46th IAH Congress - Malaga, Spain 2019

Report of Contributions

The plain of Bou Areg and the plain of Gareb, situated in the Northeast of Oriental Morocco, are characterized by a climate of the arid to semi-arid type, with an oceanic influence near the coast (ribs). The maximal and minimal average temperature are respectively 26.2°C and 12.3°C, the average yearly rainfall is 303.5 mm, while the average annual evaporation is 1501.4 ml.

According to the data of the drillings, geological formations extend from Triassic to Plio-Quaternary ages. The marls of the Miocene represent the Substratum of both ground waters, while the brown Silt represents the roof. The groundwater of Bou Areg circulates mainly in more or less clayey gravelly loam, while the aquifer of Gareb is mainly made up by shell limestones of Villafranchien. The piezo-metric map of April, 2018 demonstrates that at the level of the groundwater of Gareb, subterranean waters flows to the groundwater of Bou Areg, which is a low level area, the groundwater of Gareb is drained by Oued Selouane, and the latter, in its turn, feeds the groundwater of Bou Areg. The Three watersheds are clearly marked in the study area including four in the groundwater of Bou Areg towards the lagoon of Bou Areg and the only one in the groundwater northwards.

Concerning the hydrochemistry, the study is divided into two phases, the study of the parameters measured in situ in the countryside of April, 2018 (PH, electric Conductivity), the other study focuses on campaigns whose analysis focus on the conductivity, and the major elements. The evaluation of the quality of these waters has revealed that these waters are of a very high and normally unusable salinity whether for the consumption or for the irrigation.

Keywords: The oriental northward Morocco, Plain of Bou Areg, Plain of Gareb, Geology, Hydrogeology, Hydrochemistry, Salinization.
Groundwater vulnerability assessment in Yenagoa, Niger Delta Area of Nigeria using GIS based on DRASTIC method

This study on aquifer vulnerability assessment in certain parts of Yenagoa, Bayelsa State, Nigeria, adopted the use of DRASTIC method based on geographic information system (GIS) model to delineate areas susceptible to pollution. Seven hydrogeologic parameters were applied for the aquifer vulnerability evaluation which include depth to water table, net recharge, soil media, impact to vadoze zone, aquifer media, topography, and hydraulic conductivity. Data relating to the seven hydrogeologic parameters of the model were obtained and transformed in the model into seven maps by GIS to develop the DRASTIC vulnerability map which shows the three different forms of aquifer vulnerability namely high, moderate, and low zones. The communities within the high vulnerable zones include Swali, Agudama, Ovum, Igbogene, Okutukutu, Onopa and Okolobiri. Those within the moderate vulnerability zones are Kpansia, Etegwe, Yenezue, Azikoro, Opolo, Tombia, Biogbolo and Akenfa and in the low vulnerability zones, we have Amarata, Yenezuegene, Edepie, Azikoro, Akenfa and Okaka. The high vulnerability zones ranking was attributed to very high depth to water table, high net recharge, high hydraulic conductivity and permeability of gravelly sand in the aquifer media. The moderate vulnerability zones was due to high net recharge, low porosity of silt/clay in vadoze zone, siltyloam in soil media and high hydraulic conductivity. The low vulnerable zones was influenced by impermeability of clayloam in the soil media, low porosity of siltyclay in the vadoze zone and low topographic slope percent.
How ground gets wet: physical experiments of variably saturated flow

Monday, 23 September 2019 11:30 (15)

Hydrogeology no longer only relies on understanding of phreatic systems. Highly heterogeneous and anisotropic conditions in soil and rock comprising intergranular, fractured and karstic porosity affect groundwater vulnerability, recharge rates, drainage and dewatering practices, soil corrosivity, natural attenuation of contaminants, and integrity of infrastructure, to name a few examples. Movement of water at partial and highly variable saturation is very complex, depending on very small-scale variations in ground conditions as well as very subtle changes in moisture content. In contributing to this, a number of research projects were conducted, focused around physical experiments in the laboratory or mimicked in the field, and subjected to differing conditions pertaining to gravitational acceleration to scale the vertical dimension. Studies contribute to flow mechanisms and flow regimes of variably saturated soils and rocks, as well as the interface between, and link available theoretical understanding and empirical approaches to physical experiments and field verification experiments. Where possible, hydraulic parameters are estimated to improve the quantification of said parameters at discreet scale rather than assuming single values for bulk systems. Obvious limitations and assumptions are understood to the extent that updated flow scenarios are proposed to contribute to variably saturated flow systems. Behaviour is inferred for fractures of changing orientation, changes in medium from soil to rock, and for alternation between wetting and drying of different media. Selected experiments will be presented to highlight novel findings and the way forward.

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Session Classification : Parallel

Track Classification : Topic 5.3 - Advanced modelling tools for subsurface hydrology: from the vadose zone to deep environments
Agriculture is a significant part of California’s economic engine. It accounts for $100 billion in agriculture related business each year. Given California’s Mediterranean climate, large-scale managed aquifer recharge (MAR) is a critical element of sustainably managing water resources in California’s agricultural heartland. Conjunctive management of surface water flows in the Salinas and Kings River drainages, two of the most vital agricultural areas in the State, has been used for many years to augment natural recharge of the important underlying aquifers. Additional projects are being implemented to increase recharge efforts to offset overdraft conditions using excess river flows. Three examples of large scale managed aquifer recharge are examined: 1) an existing and well-studied MAR program in the Salinas River valley that coordinates reservoir releases to optimize groundwater recharge along the Salinas River in Monterey County; 2) a relatively new water bank along the upper Kings River that recharges seasonal excess flows using an old river channel; and 3) the planned use of agricultural fields to recharge flood flows along the lower Kings River.

The objectives and operation of each MAR system are evaluated and their overall benefit on underlying groundwater storage conditions is examined. The importance of stakeholder involvement, systematic data collection and analysis, and the potential of climate change are discussed. Benefits and challenges for each example are examined along with key criteria in the selection and design of large-scale MAR programs.

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Session Classification: Parallel

Track Classification: Topic 3 - Groundwater sustainability and governance
Geoenvironmental Investigation of the Metallic Concentration of Groundwaters in Parts of Sapele and Warri, Delta State, Nigeria

Hydrogeochemical studies have been carried out in parts of Sapele and Warri Local Government Areas of Delta State in order to determine the different hydrogeochemical facies and understand the groundwater flow regime and its effect on the chemical composition of the groundwater so as to evaluate the anthropogenic effects on groundwater quality in the study area. Twenty-five (25) water samples were taken from Sapele (18) and Warri (7) in one liter plastic cans with temperature, pH, electrical conductivity and Total Dissolved Solids (TDS) determined in-situ. The samples were then taken to the laboratory where the analyses were done using the Varian 220 flame atomic absorption spectrophotometer. Salinity and chloride in water was carried out in accordance with the American Petroleum Institute (API-RP) 45. Phosphate, Nitrate, Sulphate, Calcium, Potassium, Sodium, Magnesium and Ammonium were all determined in accordance with the American Public Health Association (APHA) 425C, 427C and 417C.

The analyses carried out indicated the presence of chloride ion as the dominant parameter. Chloride shows a negative correlation with all other parameters thus indicating that its source is from surface saline waters close to those areas with high chloride concentrations. The presence of ammonia in such high concentrations and its strong positive correlation with phosphate supports that it’s source is as a result of pollution from sewage. The positive correlation of phosphate, sulphate, nitrate and TDS also indicate pollution from sewage. GPS readings and computation of several hydrogeological parameters showed a SW direction of groundwater flow for Sapele and a SE flow direction for Warri. The presence of ammonium at levels higher than geogenic (geologically related processes) levels is a strong indicator of fecal pollution. Contamination from anthropogenic sources is mainly as a result of waste waters from brines released as by-products of oil exploration activities and leaky septic tanks.

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Session Classification : Parallel

Track Classification : Topic 3.1 - Groundwater and water security in developing countries
Prediction of Groundwater Inflow Rates to Longwall Coal Panels in Central Turkey

Monday, 23 September 2019 11:45 (15)

Pre-feasibility studies at a coal basin in Central Anatolia indicate mineable resources of about 265 million tons of coal that can be extracted via underground longwall mining during a mine life of 36 years. Since dry working conditions are prerequisite for a safe and operational mining, prediction of the groundwater inflow rates to the underground panels play a critical role. This study predicts groundwater inflow rates to determine dewatering requirements of the underground panels and evaluate anticipated impacts of dewatering on the groundwater resources. To analyze these aspects, the groundwater flow regime was modeled and calibrated under steady-state conditions using the three dimensional groundwater flow model MODFLOW SURFACT. The groundwater inflow rates were evaluated at six critical panel locations. The results indicate that groundwater inflow rates to the panels range from 26 L/s to 130 L/s, based on the location and depth of the panels. The long term impacts of dewatering on groundwater resources were assessed in terms of spring discharges that supply water to local communities and base flow rates to the Porsuk Stream. As a result of dewatering, majority of village water supply springs and fountains will dry up in the area. Furthermore, no baseflow contribution to the Porsuk Stream takes place for dewatering operations conducted at the deeper panels. On the other hand, the baseflow decreases by 33-38% for dewatering of shallower panels.

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Session Classification : Parallel

Track Classification : Topic 5 - Tools, methods and models to study groundwater
When not finding enough water is both good and bad – Methods to assess a crystalline rock, potential site for Canada’s used nuclear fuel.

The Nuclear Waste Management Organization (NWMO) was established by Canada’s nuclear energy generators in 2002 as a requirement of the Federal Nuclear Fuel Waste Act. The NWMO’s mission is to develop and implement collaboratively with Canadians, a management approach for the long-term care of Canada’s used nuclear fuel that is socially acceptable, technically sound, environmentally responsible, and economically feasible.

The site selection process began in 2010 and 22 communities expressed interest in “Learning More” about the plan. As of January 2019, there are 5 communities remaining in the process, including three in crystalline rock in northern Ontario and two in sedimentary rock in southern Ontario. Ignace/Wabigoon, in northern Ontario, was the first community to advance to borehole drilling. A 1000m vertical borehole was cored within the crystalline-rock Revell batholith and on-site testing was completed March 2018. A robust plan was in place to characterize the hydraulic response and fluid chemistry in the borehole including a suite of groundwater and porewater chemistry analyses (including pore water methods for Diffusive Isotope Exchange and Out-Diffusion); Flowing Fluid Electrical Conductivity (FFEC) logging; hydraulic packer tests; and a Westbay multi-level monitoring system.

The FFEC logging results suggested that small amounts of groundwater were entering the borehole, but sampling attempts were not successful (purging criteria not met). Groundwater samples will only be able to be collected during long-term monitoring activities. Porewater from core samples will provide additional water chemistry information. Additional hydrogeological and geochemical tools are planned for future borehole to maximize the potential for groundwater samples and to characterize the flow system including: noble gas isotopes; long-term pressure monitoring, sampling in Westbay intervals; Borehole hydraulic testing, long-term monitoring and porewater chemistry results from boreholes will support an ensemble of groundwater flow simulations based upon numerical methods to define the geosphere in 3-D (DFN models using MoFrac).

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Session Classification : Parallel

Track Classification : Topic 5.4 - Innovative approaches for understanding groundwater flow systems
Improving Freshwater Security in the Caribbean using Managed Aquifer Recharge

Monday, 23 September 2019 16:00 (60)

Climate change poses a major threat to the freshwater supply in the Caribbean region due to a variety of factors including the small size of the countries, an overwhelming dependence on rainfall for the supply, the potential devastating impact of hurricanes on the water supply, and the proximity of groundwater aquifers to the Caribbean Sea and Atlantic Ocean. As part of an effort to improve the freshwater security and sustainability in the Caribbean region, a study was undertaken on behalf of the Interamerican Development Bank to identify suitable managed aquifer recharge strategies (MAR) for the region. This study focused on the technical and socio-economic dimensions of MAR, subsurface considerations and constraints when employing MAR technologies and methodologies, MAR management and governance, costs to implement and operate MAR programs, and case studies where MAR has been employed in or near the region. A decision tool was developed to assist in assessing potential implementation of MAR schemes.

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Session Classification : Poster with refreshments
Track Classification : Topic 1 - Groundwater assessment and management
Background: Several diseases have caused by contamination of surface and groundwater.

Aim of the work is to investigate the impact of iron overload in drinking water on liver pathology.

Materials and Methods: Samples of drinking water, blood and true cut liver biopsies taken from selected inhabitants. Those inhabitants were suffering from liver disorders. Samples of water, blood and true cut liver biopsies after having informed consent taken and undergone for determination of iron level. Measurement of iron level in water samples was carried out in duplicate with the use of GBC atomic absorption spectrophotometer, Taco company (Australia). Analyzed for serum iron level with a micro lab 200 spectrophotometer by using Iron-B kit, Biocon company (Germany).

Results: the mean value of iron in groundwater samples is higher than those permissible limits and then those of surface drinking water. Comparison between iron level in drinking water and human blood samples shows positive relationship. The control group depended on drinking surface water and had normal liver function tests, whereas the patient group that depended on drinking groundwater had abnormal values in liver function tests. These data suggest that the polluted iron drinking water is the reason for the liver disorder of the patients. Siderosis was apparent among those patients drinking polluted iron water in comparison to control cases. The siderosis appears to be responsible for resistance to treatment of HCV and progression of fibrosis.

Conclusion: The accumulation of iron in liver leads to fibrosis. Iron depletion therapy could interfere with fibrosis development and possibly reduce the risk of hepatocellular carcinoma (HCC).

Keywords: Water, blood, liver, Iron

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Session Classification : Poster with refreshments
Track Classification : Topic 8 - Groundwater quality and pollution processes
Progressive release of nitrate from agricultural vadose zone delays groundwater quality improvement response to remediation

Friday, 27 September 2019 09:55 (15)

Excessive nitrate leaching from crop production has been linked to elevated nitrate levels in groundwater. Beneficial Management Practices (BMPs) have been implemented to reduce nitrate leaching, but monitoring rarely detected improvements in underlying groundwater quality. A study (2011-2016) was conducted in a potato-grain-forages rotation field in Prince Edward Island (PEI), Canada, to understand the processes that govern this lack of a positive response. The field consists of fine sandy loam soil and is underlain by 7–9 m of glacial till, which overlies the regional fractured “red-bed” sandstone aquifer. The water table is generally located in the till close to the till/bedrock interface. Field treatments included one field zone taken out of production in 2011 with the remaining zones kept under a conventional potato rotation. Taking potato land out of production simulated an extreme scenario of nitrate reduction as a BMP and allowed an assessment of the effects of soil, weather and geology on nitrate transport without adding confounding factors related to management practices. Multilevel piezometers were installed to monitor the responses of groundwater nitrate level to the contrast treatments. Soil sampling detected a significant amount of nitrate after potato harvest in fall 2011. This nitrate was detected in the tile drains in late fall 2011, in the overburden at a depth of ~3.5 m in December 2012 by coring and in the aquifer (peak concentration) in early spring 2014 by the multilevel systems. These data suggested that the nitrate migration followed a uniform flow path in the till and the ongoing release of nitrate from the vadose zone created a persistent nitrate plume in the underlying aquifer. This finding implies that agricultural vadose zones can store a significant amount of nitrate with a substantial delay in release to the groundwater.

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Session Classification : Parallel

Track Classification : Topic 8 - Groundwater quality and pollution processes
INTEGRATED WATER RESOURCES ASSESSMENT IN THE DRY CORRIDOR OF EL PROGRESO, GUATEMALA

Friday, 27 September 2019 12:00 (15)

The Dry Corridor is a hydroclimatic region in central Guatemala covering an area of 11,000 km2 and characterized by frequent droughts affecting water supply for competitive uses during summer. Hydrogeologic data for the Department of El Progreso has been integrated in order to evaluate water availability. Water well inventory and characterization reveal two different hydrogeologic settings: a) a geothermal system hosting groundwaters contaminated with sodium, chloride, and boron, and b) a low yield (0.63-2.2 L/s) fractured-schist shallow aquifer. Monthly river discharge monitoring by wading identifies strong seasonal variations associated with changes in mean precipitation in the wet season from May to November (30 – 228 mm) and in the dry season from December to April (0 – 15 mm). Summer baseflow varied from 0.186 to 0.555 m3/s during the critical year 2017. Water availability during summer is also highly affected by water withdrawal without regulation for irrigation and by a dam constructed for domestic water supply causing streamflow depletion. In order to meet the socioeconomic needs of water for the local population during summer it is essential to design a water resources management plan focusing on inventory and organization of water users and water use efficiency.

Keywords Guatemala, Water resources, Dry corridor, Drought, Water availability.

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Session Classification : Parallel

Track Classification : Topic 9 - Groundwater and socio-economic development in Latin-America
Seasonal signals of stable isotopes in precipitation combined with measurements of soil water content have been used for a quantitative estimation of groundwater recharge rates. This study investigates the applicability of the piston flow principle and the peak shift displacement method for assessing recharge in a humid Nordic region located in Quebec in Canada to estimate groundwater recharge rates. Two different sites in the same unconfined aquifer were tested using measurements of soil water isotopes 18O/2H and of volumetric pore water content in core samples (2.45 m for one site and 4.15 m for the other) obtained along the vadose zone down to the groundwater table at the two sites. The end of snowmelt, fingerprinted by the isotopes, was identified in the pore water of the sediment profiles. The peak shift method was observed to be accurate in certain specific conditions inherent to the soil properties of the investigated sites, namely, when the soil properties are homogenous. Peak shift displacement and piston flow principle did not allow the accurate estimation of recharge in heterogenous environments, nor when the topography causes runoff/runon. At one of the two sites, recharge from the snowmelt could not be estimated because of heterogeneity in the lower part of the vadose zone. At this same site, however, the later post-snowmelt recharge could be estimated because the upper part of the vadose zone was homogenous. At the other of the two sites, runoff/runon phenomena prevented the accurate calculation of infiltration and thus recharge. These two different site effects, heterogeneity in the first site and runoff/runon in the second site, were identified as being limiting factors for an accurate assessment of recharge. This study recommends the use of the peak shift method for humid Nordic regions characterized by homogeneous and thick vadose zones with limited site effects.
Effects of water table depth on the hydrological process in the unsaturated zone

Water table depth is a critical factor affecting infiltration recharge and groundwater evaporation, both of which are key aspects of the hydrological process in the unsaturated zone. To evaluate the effect of water table depth on the hydrological process in the unsaturated zone, a lysimeter experiment incorporating a 1-year-long bromide tracer test was conducted to determine the unsaturated zone flow process under different water table conditions. The experimental results clearly indicated that water table depth determines the storage capacity of the unsaturated zone, thereby affecting the hydrological process in the unsaturated zone. The decline of the water table increased the maximum water deficit that consumed the infiltrated water and reduced the actual recharge quantity. Evaporation only affected the unsaturated zone above the extinction depth of evaporation (EDE), and consequently, groundwater evaporation tended to be extinct in association with the decline of the water table. The relative position of the water table and EDE changed the unsaturated zone flow. When the water table was above the EDE, downward and upward fluxes were dominated by infiltration recharge and groundwater evaporation, respectively, but would restrict each other, as demonstrated by the negative relationship between an irrigation event and groundwater evaporation. Soil water moved predominantly downward when the water table was below the EDE; a deep unsaturated zone entailed a long infiltration path, which smoothed the temporal variability of the recharge rate and increased the time lag in recharge. Groundwater evaporation caused the upward transport of bromide, which proved to be significant for the evaluation of evaporation quantity. The application of the bromide tracer method should meet certain prerequisites such as application of a rain shelter and appropriate injection depth. The bromide tracer was proved to be efficient for tracing the unsaturated zone flow and presents an innovative method for evaluating groundwater evaporation.

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Session Classification : Parallel

Track Classification : Topic 5.3 - Advanced modelling tools for subsurface hydrology: from the vadose zone to deep environments
Assessing groundwater recharge and evapotranspiration in a Nordic humid region dominated by snowmelt

Monday, 23 September 2019 11:15 (15)

Groundwater recharge in Nordic humid regions is mainly dominated by snow melt. Estimating recharge rates and determining evapotranspiration by determining the influence of different vegetation types on soil water fluxes represents a significant challenge. The stable water isotopes $\delta^{18}O$ and $\delta^{2}H$ can be used to investigate the water fluxes in the unsaturated zone, given that the isotope ratios of precipitation and snow melt are preserved in the pore water of sediments. These water isotope ratios in unsaturated zone profiles represent an inherent fingerprint of the infiltration history. Measuring the volumetric water content in these profiles, and then correlating these profiles with the isotopic profiles, makes it possible to determine the quantity of water that has infiltrated during different periods. The objectives of this study are to (i) understand snow melt infiltration at sites experiencing thick snow coverage during winter, (ii) calculate groundwater recharge rates, and (iii) estimate evapotranspiration rates at sites presenting different land covers (bare soil, bush vegetation coverage and mature forest coverage). At the study site, we sampled sediment cores at three different locations to analyse soil water content and isotope ratios in pore water. Groundwater recharge rates were calculated using the peak shift method. Using water balance values, we were able to additionally assess evaporation and transpiration at the different sites, with and without vegetation, and also to assess the influence of the vegetation cover on evapotranspiration and recharge. This study confirms the accuracy of the peak shift method for estimating recharge and for assessing the effects of field site characteristics and soil coverage on evapotranspiration rates.

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Session Classification : Parallel

Track Classification : Topic 1 - Groundwater assessment and management
The North China Plain (NCP) is one of the biggest groundwater systems in the world, and the development and utilization of groundwater has led to severe land subsidence. The NCP has more than 80% of the total area of severe subsidence in China, so the situation of prevention and control of land subsidence is severe. Due to diverse sedimental environment, different geological conditions, and intensive groundwater abstraction, the mechanism of land subsidence is complex. With the help of earth observing technique and traditional monitoring tools, the disaster process of land subsidence was monitored, and the developing history and current situation were analyzed. Also, the difference features of land subsidence and the mechanism of hysteretic deformation were analyzed with the help of strain-stress diagrams and soil mechanics tests. The results show that the subsidence areas are mainly located in the areas of the Quaternary sedimentary depressions, having characteristics of west-east sub-zone and north-south subsection. The major contribution layers to the land subsidence have varied with the change of groundwater abstraction layers. The drought is an important and indirect factor enlarging the scale of land subsidence by reducing natural recharge and leading to the increase of groundwater abstraction for emergency water supply. The hysteresis of land subsidence is obvious, and the time of hysteresis can last for twenty-five years. Besides the consolidation, the creep is another important reason for the hysteresis which can reach 28.3% of the total deformation for the Late Pleistocene strata in the Cangxian uplift. The deformation characteristics of the soil layer bear strong relationship to the physical characteristics and variation pattern of groundwater levels. The strata at different depths have distinct deformation characteristics such as elastic, visco-elastic, and visco-elastic-plastic deformations, and shallow aquifer groups indicate typical elastic deformation.

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**Session Classification:** Poster with refreshments

**Track Classification:** Topic 1 - Groundwater assessment and management
Conflicts and resolutions of shared waters in the Americas

Monday, 23 September 2019 15:00 (15)

To solve one of the grand challenges facing society today: energy, water, climate and food, natural scientists and social scientists must work together. A new framework is required for bringing together hydrology and social sciences: This way, economics, administration, law, psychology, arts and humanities, are here combined into social sciences.

From thousands of years (3000 BC) to the latest war conflict in Syria (2015), water has been a source of conflict between countries and even within a country related to water resources, water systems, and national and international security. Solutions to water conflicts have been part of history too, cooperation and good will being the key components of the solutions.

In this presentation, more than simple solutions to water problems, we try to describe resolutions to water conflicts by means of an explanation of a problem or a puzzle, and a way of looking at, explaining and writing up a water problem that became a conflict in a systematic fashion. Drawing on examples from the American hemisphere, from Chile/Bolivia to Canada/US, we examine surface water, groundwater and wetlands from scientific, socioeconomic and political perspectives, and propose an interdisciplinary socio-hydrology frame for resolving or concluding water disputes or disagreements.

International organizations play the largest role in mediating water disputes and improving water management. From scientific efforts to quantifying water pollution, to the World Trade Organization’s efforts to resolve trade disputes between nations, the varying types of water disputes can be addressed through the current framework. Yet water conflicts that go unresolved become more dangerous as water becomes more scarce and global population increases.

We present quick cases of real or apparent situations of water conflicts in the Americas including Bolivia-Chile, Brazil-Argentina-Paraguay-Uruguay; the CGSM in Colombia; Costa Rica-Nicaragua; and Mexico-USA.

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Session Classification : Parallel

Track Classification : Topic 3 - Groundwater sustainability and governance
Optimization of pilot points distribution in inverse modelling- A case study from Qatar Aquifer

Monday, 23 September 2019 12:00 (15)

Two approaches are commonly used for model calibration, namely the zonation and the pilot-points method. While the zonation approach assumes an abrupt spatial change in parameter values, the pilot-points method produces smoothly distributed parameters, however, the number and placement of the pilot-points can be challenging.

The objective of this study is to explore the effect of pilot-points number and locations on the calibrated parameters. The northern aquifer of Qatar is used as a case study, using a 3D groundwater flow model. A numerical model of this aquifer was developed using MODFLOW and the model was calibrated using PEST package using historical data of groundwater levels. The model was run several times using a variable number and distribution of pilot points. The Root Mean Square Error for all the runs (corresponding to different configurations of pilot-points) was maintained under a certain threshold. A statistical analysis of the calibrated parameters was then performed to evaluate how far these parameters are impacted by the pilot-point locations. Finally, a new methodology for Optimisation of pilot points locations was proposed using recharge and piezometric maps.

The results showed that the pilot-points number, locations, and configurations have a substantial impact on the calibrated parameter, especially in the high permeable regions. The outcome of this study may help focus on areas of high uncertainty where more field data should be collected to improve model calibration. It also helps placement of pilot points for a robust calibration.

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Session Classification : Parallel

Track Classification : Topic 5.3 - Advanced modelling tools for subsurface hydrology: from the vadose zone to deep environments
Integrating Fiber-optics distributed temperature sensing and electromagnetic geophysics data for multiscale characterization of GW-SW interactions in heterogeneous streambeds.

Monday, 23 September 2019 12:00 (15)

Groundwater-surface water interactions play a key role in determining accurate estimation of groundwater resources. However, the quantification of water exchanges occurring along and across multiple scales of streambeds still represents a big technical challenge. Given the difficulties to directly measure the seepage and/or infiltration volumes, indirect observation of water exchanges becomes an interesting alternative approach. Temperature profiles together with vertical hydraulic gradients of the sediment allow the calculation of vertical flux exchanges, but the values calculated from such few locations may not be representative of the spatial and temporal variability of exchanges. Conversely, distributed techniques such as fibre-optics distributed temperature sensing provide the opportunity to infer groundwater discharge and surface water infiltration based on the distinct thermal footprints they leave in the sediment-water interface. Moreover, the technique can capture not only the spatial heterogeneity of these patterns attributable to groundwater but also the areas of surface water infiltration during transient events. Electromagnetic induction geophysics can complete the exploration of heterogeneity by identifying the regions of preferential groundwater-surface water interaction based on the distribution of hydraulic conductivity values derived from electrical conductivity observations. Furthermore, the integration of the traditional point data with the high-resolution data from distributed techniques improves the performance of flow and heat transport models used for modelling groundwater-surface water interactions. The study builds a MODFLOW-MT3DMS model to simulate groundwater-surface water interactions in the same study site in East Germany where point and distributed data was collected. The FloPy python suite helps to incorporate the high-resolution data of distributed techniques into the 3D model. The study evidences how models based on distributed geophysics data outperform those defined on sediment cores. Secondly, the model validates the reliability of fibre-optics to identify groundwater-surface water exchanges based only on the spatial and temporal evolution of temperature anomalies in the sediment-water interface. Additionally, 3D flux estimates from the 3D flow and heat transport model cast doubt on the accuracy of the 1D vertical estimates of groundwater-surface water interaction obtained from point techniques. Altogether, the study enables discussing the advantages of using distributed techniques for the investigation of groundwater-surface water interactions with a multi-scale approach while showing the potential of 3D flow and heat transport models fed with this data for upscaling of local groundwater-surface water measurements.

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Session Classification: Parallel

Track Classification: Topic 5 - Tools, methods and models to study groundwater
Preliminary evaluation of nitrate groundwater pollution and remediation in Shimabara Peninsula, Nagasaki, Japan

Thursday, 26 September 2019 17:00 (15)

Nitrate pollution in groundwater is a serious environmental problem in the Shimabara Peninsula, Nagasaki Prefecture, Japan. For efficient countermeasures and remediation of the groundwater, numerical simulation may constitute a powerful tool. Along this line, we developed a numerical model to improve the understanding of transport processes in the nitrate pollution and we evaluated the effects of remediation countermeasures by using the FREEWAT software including MODFLOW as numerical engine. The entire area of the Peninsula was represented by a 200 x 200 m grid. Based on the relationship between elevation and observed hydraulic head in steady-state conditions, boundary conditions were set for hydraulic head along seaside and mountainside boundaries. We estimated spatial variation of evapotranspiration based on spatial varying mean precipitation and temperature. Then, groundwater recharge was calculated using the UFZ package. The steady state results of groundwater flow simulations reproduced observed hydraulic head data. We then calculated distributed potential nitrate load for the solute transport simulations using statistical data from agriculture and forestry for the Shimabara City. The distribution of high nitrate loads well fit the agricultural land-use. Monitoring data confirmed that polluted groundwater is typically located downstream of high potential nitrate load areas. According to the numerical transport simulation results (performed using MT3DMS), the general trend of concentration change well agreed with observation during the past 44 years. Remediation simulations indicate that it will take about 18 years for groundwater concentrations to fall below Japanese drinking water standards. The pre-requisite is a 40% reduction in nitrate load of the source zone. In case of a 50% reduction, the nitrate concentration could be below the standard within 12 years.

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Session Classification : Parallel

Track Classification : Topic 8 - Groundwater quality and pollution processes
Diffusion and weathering of oil spill in Daya Bay, the South China Sea

Monday, 23 September 2019 17:15 (15)

With the development of marine resources and marine transportation, oil spill accidents occur frequently which threaten the marine ecological environment and human life. In this paper, an oil spill model was established. With discretizing two-dimensional shallow equation by finite element method, the oil spill hydrodynamic-numerical model was established. As the water boundary condition was defined by harmonic analysis method, the model was verified by measure tidal level data. The boundary treatment method of multiple islands and complex shoreline was proposed. Monte Carlo Method is used to simulate the diffusion and drift of oil spill, Euler-Lagrange method is used to track the film centroid and oil film boundary, and a random number was added to indicate the randomness of oil film expansion. The diffusion drift of oil film was verified by flume test. At the same time, this model considered the weathering process of evaporation, emulsification and entrainment of oil spills, and calculated the onshore adsorption of oil spills. The model is applied to Daya Bay, South China Sea, the oil spill behavior and destination under different residual currents were simulated and calculated, which provides a theoretical basis for the prevention and emergency treatment of oil spill accidents.

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Session Classification : Parallel

Track Classification : Topic 8 - Groundwater quality and pollution processes
Study of the clogging process in a semi-arid region
(Wadi El Himmer, Morocco)

In semi-arid regions, Managed Aquifer Recharge (MAR) is seen as an efficient solution among others for protecting groundwater resources. Clogging is one of the major issues that can reduce the durability of recharge facilities. As a consequence of clogging of soils by suspended matter, permeability, and porosity, and therefore exchange between surface water and groundwater are reduced. To our knowledge, few researches have studied the mechanism of clogging of the MAR in a semi-arid region according to hydrologic conditions of the field.

The main objective of the present work is to study the clogging process of recharge sites in a semi-arid region (Wadi El Himmer, Morocco). These recharge sites consist of a percolation tank and recharge releases, which retard and distribute the flow to facilitate infiltration into saturated zone. Field measurements are conducted to quantify the thickness of the deposits (Cake) according to precipitation at different recharge sites. To realize these measurements, wooden pickets were implanted at different locations of the recharge sites. After eight weeks of exposure to hydro-meteorological conditions, the thickness of the deposited (suspended matter) layer was measured on each picket. In order to facilitate the interpretation of results, the kriging method was used to interpolate obtained measurements.

A significant variation in cake thickness was observed at each recharge site following the flow direction. The layer deposited is mainly dominated by red clays and silts. These results prompt us to investigate the impact of these deposits on the deep clogging.

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Session Classification : Poster with refreshments

Track Classification : Topic 1 - Groundwater assessment and management
Hydrogeochemical and isotopic investigation of the Metlaoui range springs in southwestern Tunisia

Thursday, 26 September 2019 16:00 (60)

The Metlaoui mountain springs constitute the water sources used for oasis irrigation in Metlaoui and Chebika regions in southwestern Tunisia. Springs and wells from Chott El Gharsa plain have been analyzed for main components (Na+, K+, Ca2+, Mg2+, SO42-, Cl-, HCO3-, NO3-, Br-, F- and I-), trace elements (Li, B, Ba, Cu, Al, Zn, Rb, and Ni), δ18O and δ2H of water. The etiology behind the water origin of springs is the main research’s dilemma that were investigated using geological, hydrochemical, and stable isotopic techniques. Chemical composition of spring water vary between distinct geological units and reflect the geochemical characteristics of the surrounding rocks. Springs emerging from the geological unit "Kef Eddour" show higher elemental concentrations than those located in the "Beglia" sand unit. Dissolution of evaporates within the Eocene limestones is the main source of mineralization. Isotope ratios (18O/16O and 2H/1H) provide further information on the connection of the Metlaoui springs to the unsaturated and saturated zones. Springs Laachach, Chebika, Beidha, Soundoss, Thalja and Foum El Khanga plot along the evaporation line. While springs Tahar, Marchane, Ameur and Goussiba connected to the shallow unsaturated zone of Eocene limestones indicate a mixing trend of evaporation-dissolution processes. However, Hamda spring undergoes a higher evaporation process and behave as a closed system. Summarizing the hydrochemical characteristics of springs and exploring their genesis are of importance for their preservation.

Keywords: chemical composition; isotopic ratios (δ18O and δ2H); springs; Metlaoui Mountains; Southwestern Tunisia.

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Session Classification : Poster with refreshments

Track Classification : Topic 5.4 - Innovative approaches for understanding groundwater flow systems
Physico-chemical as well as microbiological analysis of groundwater from hand dug wells and boreholes in Paiko, Northcentral Nigeria was conducted to determine their suitability for drinking purpose. The water from the hand dug wells are predominantly mixed calcium magnesium chloride (CaMgCl) water while those from boreholes are calcium magnesium bicarbonate water (CaMgHCO3) facies. The results showed elevated cations and anions concentration in the hand dug wells in addition to the water being slightly acidic. Also, the nitrate concentration in the hand dug wells is above the maximum permissible WHO and Nigerian standard for drinking water quality. Microbiological analysis revealed Total Coliform Count of 100cfu and 360cfu in the hand dug wells signifying faecal contamination. The study revealed that improper sewage systems, use of agro-chemicals as well as poor waste disposal is responsible for the poor water quality as well as elevated concentration of nitrate in hand dug wells, and as such the shallow aquifer groundwater in the area not safe for the drinking purpose with respect to all the parameters taken together. The groundwater samples obtained from boreholes are generally of better quality except BH 1 which has evidence of recent faecal contamination.
The eastern zone of Terceira Island (Azores) is divided by normal faults oriented NW-SE that defines the Lajes graben. The subterranean hydrology of this depression is characterized by the occurrence of ten perched aquifers, differentiated by local faults, and by a basal aquifer, which is presumed to be unique at island.

The recharge of these water systems takes place the central sectors of the island, while the discharge occurs in the submarine platform that surrounds the island, in the intertidal zone and in a series of wetlands and lagoons located in the coastal bay (e.g. Praia da Vitoria’s, Belo Jardim’s and Pedreira do Cabo Praia’s wetlands). The groundwater flow of the Lajes graben presents in some places situations where the circulation is atypical, without the expected radial characteristics, explainable by the presence of faults with a differential hydraulic behavior.

In this work, a qualitative analysis of the water in the southern sector of the Lajes graben is carried out, where fuel spills were referenced, based on analytical data wells for water supply and coastal wetlands.
Impact of sea level rise and Sustainable groundwater management in in Kalpitiya Peninsula, Sri Lanka

Sri Lanka is an island which is vulnerable to sea level rise. Therefore, sea level rise and its impact directly face to coastal region and their population. It is evident that most of the future settlements will be located along the Coastal Belt of Sri Lanka while the global warming tempted Sea Level rise in the Indian Ocean could have a number of physical impacts on the country as an island. One of the major consequences is the depletion of coastal ground water resources due to salt water intrusion leading to potential shocking impacts on Coastal Population. In the contemporary context, ground water has become a diminishing resource in the dry zone coastal areas of the island due to the vast utilization and over exploitation. The study was conducted to identify the sea level rise and its impacts on coastal water in Kalpitiya Peninsula, west coast of the Sri Lanka, using geographical Information System and Remote Sensing. Both natural and human factors apply to sea level rise and its impact evaluation, which includes sea level, tide, land use, ground water and several physical and human factors were analyzed by spatial analysis methods in ArcGIS 10.1 and suitable statistical analysis methods on several statistical software. The significance of ground water usage in the context of demographic and economic conditions of the case study area was reviewed using secondary data. The results of the analysis indicate that, the Dry Zone Coastal Ground Water table facing de-facto deprivation under the threat of Sea Level Rise. Accordingly the sustainability of dry zone coastal settlements is in a critical need of due attention since the growing population of the area do not possess the capacity to sustain without the water they need for the daily life.

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Session Classification :  Parallel
Track Classification :  Topic 2 - Groundwater and climate change
BOREHOLE YIELD ESTIMATION FROM ELECTRICAL RESISTIVITY MEASUREMENTS – A CASE STUDY OF GARU TEMPANE AND BAWKU WEST DISTRICTS, UPPER EAST REGION, GHANA

Monday, 23 September 2019 18:00 (15)

Electrical resistivity survey has proven to be an effective tool for groundwater exploration and has been widely embraced to help reduce the drilling of unsuccessful wells. Currently, information from electrical resistivity survey is often used in locating points for drilling, but it does not give indication of the yield of the borehole. The lack of this information therefore sometimes results in the drilling of dry and marginal wells. This study therefore looks at the possibility of using resistivity data, which is readily available from electrical resistivity surveys for groundwater exploration, for estimating the yield of yet to be drilled borehole. The study was limited to the Garu Tempane and Bawku West Districts. Secondary data on Vertical Electrical Sounding (VES) and drill logs for 49 boreholes in the selected districts were used. The thicknesses, apparent resistivities, longitudinal conductance and transverse resistance of the various subsurface layers of the boreholes were determined from drill logs and VES data. Correlations between borehole yields and the third layer apparent resistivity, longitudinal conductance and transverse resistance were then investigated to develop regression models for estimation of the borehole yields. The results showed that the third layer is fractured and contributes significantly to borehole yields in the area; hence the fractured subsurface layer is of primary interest to be considered in groundwater exploration and estimating potential borehole yield from VES data. The results obtained further indicated that apparent resistivity, longitudinal conductance and transverse resistance had good exponential and positive linear relationships with borehole yield.

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Session Classification : Parallel

Track Classification : Topic 5 - Tools, methods and models to study groundwater
In undifferentiated geologic terrains as Kintampo South District in Brong-Ahafo Region of Ghana, there is the need for extensive groundwater exploration before suitable sites are selected for drilling. There is therefore the need to augment the groundwater investigation to improve the success of drilled holes and to reduce the cost of drilling unsuccessful wells. The use of the polluted surface waters which are the primary water supplies within the District has resulted in outbreak of several water borne diseases. An alternative water supply system which is reliable and cost effective is imperative to complement the traditional surface water supply system. This study seeks to integrate Electromagnetic (EM) and Vertical Electrical Sounding (VES) methods to locate suitable aquifers for groundwater extraction within the Kintampo South District. Hydro geological investigations were carried out within ten selected communities within the District using the EM and VES geophysical methods. The EM was used for horizontal profiling and selected anomalous points/areas further investigated with the VES, after which points were ranked and finally selected for drilling. The electromagnetic profiling was efficient in detecting anomalies and possible water filled fractures as was further confirmed by the VES survey. Ninety percent (90%) of the drill points selected for drilling produced wet wells which increased access to water, sanitation and hygiene (WASH), and a reduction in water borne diseases and other WASH related issues within the district. It is recommended that more than one geophysical method should be combined for better and effective results. This method can be used to map out potential drilling points for groundwater supplies/help to improve on sites selection and reduce the drilling of unsuccessful wells. This will enable the limited financial resources in developing countries to be channelled into providing boreholes with substantial yields.

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**Session Classification**: Poster with refreshments

**Track Classification**: Topic 5 - Tools, methods and models to study groundwater
Hydrogeological Characterization of Coastal Aquifers in Seocheon Watershed, Korea: A Case Study of Groundwater and Seawater Interaction

Tuesday, 24 September 2019 16:00 (60)

For better understanding of the interaction of groundwater and seawater in coastal aquifers hydrogeological studies have been carried out. The regional water quality of groundwaters, reservoirs, and stream waters surrounding the study area was determined with a total of 100 samples in pre- and post-monsoon seasons of April to May and September to October in 2018 by analyzing the major cation/anion and radon contents. The main water quality types of groundwater, reservoir, and stream water are Ca-Cl, Ca-HCO3, and Ca-Cl, respectively. Groundwater and seawater interaction has been evaluated for the identification of tidal effect by time series analysis, hydrogeophysical method, and 2-dimensional semi-analytical solution. The time series analysis shows the groundwater level and freshwater/saltwater interface are influenced by 73% and 76%, respectively, mainly governed by tidal effect. In the result of electrical resistivity survey at the surrounding area of monitoring wells the subsurface area of the measuring line of 240~255m reflects the tide effect of the coastal aquifers. The analytical solution, on the other hand, reveals little changes of the interface, resulting that the interface depth is far away from the point in which the upper groundwater level changes occur due to the tidal effect. The preliminary results shown in this study need to be identified by further detailed investigations.

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Session Classification : Poster with refreshments

Track Classification : Topic 5 - Tools, methods and models to study groundwater
Regional Distribution of Rn-222 Concentrations in Hot Spring Waters of South Korea

Thursday, 26 September 2019 16:00 (60)

Natural occurring radionuclides in hot spring waters are the major public concerns associated with a longterm health hazard. This study focuses on the characterization of regional distribution of Rn-222 concentrations in hot spring waters of South Korea. A total of 40 samples from 17 different sites were collected and analyzed by liquid scintillation counting technique using LKB Wallac Quantulus 1220 liquid scintillation counter (LSC) equipped with pulse shape analyzer (PSA). Their concentration levels were used to construct the detailed Rn-222 distribution maps. The strong correlations are observed between chemical parameters (temperature, EC, pH, Eh) and the concentrations of Rn-222. The Rn-222 concentrations range from 0.3 to 809 Bq/l with an average of 84.8 Bq/l. Of the 40 samples, 11 samples (27.5%) exceeds the World Health Organization (WHO) radon level limit of 100 Bq/l and 4 samples are higher than 148 Bq/l an action level of Rn-222 concentrations recommended by United States Environmental Protection Agency (US EPA).

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Session Classification : Poster with refreshments

Track Classification : Topic 5.4 - Innovative approaches for understanding groundwater flow systems
Impacts of Climate Change on Groundwater –
results from the BINGO project

Monday, 23 September 2019 11:15 (15)

Climate change impacts on groundwater usually take a longer time-lag to occur than in surface water resources, depending on the inertia of the aquifer, which are further enlarged by land use changes, population growth, changing socio-economic conditions, hindering the sustainable management of groundwater resources, which should also take into account the ecosystems’ needs. Climate change studies usually are long term (2070 or 2100) while decision-makers define policies under short term frameworks. Trying to overcome this problem, BINGO project analysed the impacts of climate change, including extreme events, on the water cycle for time horizon 2024.

The analysis of climate change impacts on the aquifers Tejo-Margem Direita & Tejo-Sado/Margem Esquerda, Aluviões do Tejo (downstream Tagus Basin), starts by using climate data from 10 climate realizations and their ensembles, generated by regional climate model MiKlip developed by FUB. These data are used by BALSEQ_MOD model to calculate recharge, which is an input data for the 3D FEFLOW aquifer’s flow model. Results are presented for maximum recharge conditions (from MiKlip R1 realisation), which show a recharge change of +49.1%, +37.6%, +29.4%, for each of the aquifers, respectively. This is translated in piezometric rises between +2 and +5 m and flooding of several areas. For the minimum recharge conditions (from MiKLIP R3 realiziation) recharge changes range from -10.4%, -20.6%, -11.6% respectively for the same aquifers, translated into piezometric changes between -2 and +10 m. For the ensembles recharge conditions (from MiKlip R1_R10) ranges from + 5.4%, + 4.2%, +0.2% respectively, translated into a negligible piezometric change. Once the ensembles scenario is the most likely for 2024 the results show that studies for the short range are not very useful in supporting adaptation strategies, particularly for large aquifers as in this case, and instead what is required is a policymakers’ paradigm shift from the short range to the long range when dealing with climate change. That means, act now in order to be able to cope with the changes that are in store for the future instead of relying only on short term studies.

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Session Classification : Parallel
Track Classification : Topic 2 - Groundwater and climate change
Impact of Geogenic Arsenic Mobilisation On Drinking Water Production From Glauconitic Sand Formations: Origin, Processes and Mitigation Strategies

Thursday, 26 September 2019 16:00 (60)

In the southern part of the Netherlands, in the Province of Noord-Brabant, groundwater quality is threatened by multiple factors, increasingly challenging the ability to cost-efficiently produce drinking water. Particularly, intensive agricultural land use resulting in relatively high nitrate loading in addition to local sources such as former landfills and industrial contamination, is threatening drinking water production potential from shallow aquifers. This is, for example, reflected by increasing sulfate concentrations resulting from pyrite oxidation. As a consequence, increasingly deeper aquifers have been targeted for drinking water production. In addition to increasing risks of induced salinization while producing at greater depths, several drinking water production sites have shown strongly elevated arsenic concentrations (up to 40 μg / L) at depth, associated with the deeper groundwater wells. In view of ensuring safe and cost-efficient drinking water production in the future, this study focused on gaining insight into the underlying hydrogeochemical processes that determine the extracted groundwater quality and how these processes are likely affect the future quality development. Focusing on the inorganic groundwater quality and the hydrogeochemical processes that contribute to the increase of the concentration of arsenic, sulphate and metals in the groundwater, results show that pyrite oxidation is the most important mechanism in the shallow groundwater resulting in the mobilization of arsenic and heavy metals (nickel, zinc and cobalt). Although locally arsenic and nickel concentrations exceed drinking water standards, these constituents do not breakthrough along with sulfate in the groundwater abstraction wells at intermediate depth, that arsenic and nickel are strongly retarded following their mobilization by nitrate induced pyrite oxidation. The elevated arsenic concentrations at greater depths therefore unrelated and detailed groundwater and sediment analysis in combination with sediment reactivity experiments indicated that the weathering of glauconite in the deeper sands (125-165 m-below) of shallow marine origin is the most likely origin, based on hydrogeochemical parameter correlations and observed acidity buffering capacities. While the spatially variable arsenic concentrations in the region in these sand formations observed in these formations are likely related to syn-depositional arsenic incorporation during glauconite formation, elevated arsenic concentrations are expected to form a long lasting challenge for the drinking water production from these aquifers. Ongoing research is currently exploring several approaches, including well management and water treatment, to cost-effectively remove the elevated arsenic concentrations during drinking water production.

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Session Classification : Poster with refreshments
Track Classification: Topic 8 - Groundwater quality and pollution processes
Determining the Source of Deicing Salt Contamination to Bedrock Wells Using Downhole Logging Methods

Friday, 27 September 2019 09:55 (15)

In the Northeast U.S. new types of highway winter deicing procedures along with increasing amounts of salt usage is resulting in an ever increasing number of salt contaminated bedrock wells. The town of Sherman, Connecticut is a case in point. The town has many such open borehole wells drilled into metamorphic bedrock. Despite years of periodic water quality monitoring, and thorough temporal and spatial analyses, the source(s) of the salt contamination has remained elusive.

To further characterize the nature of the problem and to define possible solutions, we conducted both conventional and non-conventional borehole logging on 5 contaminated wells. Conventional logging included: fluid temperature, specific conductivity, gamma, caliper, acoustical borehole imaging, and heat pulse flow meter (HPFM) logging under ambient conditions. HPFM was also conducted under pumping conditions. Non-conventional logging consisted of water quality profiling with a sonde which measured temperature, electrical conductivity, pH, ORP, and Dissolved Oxygen. We also applied the Dissolved Oxygen Alternation Method to assess borehole flow conditions. Finally, active flow zones were sampled using Hydrasleve samplers. In general it was determined that the shallow depth to rock, steeply dipping shallow fractures and poorly sealed casing into rock were the main reasons the wells were impacted by the use of salt. Piling of salted snow near wells and well proximity to salted runoff surfaces were also contributing factors. An interim remediation measure was developed which entails flushing wells following the snow season and the use of simple test kits for everyday monitoring. Long term remediation measures were developed to manage runoff surfaces near impacted wells and minimize unnecessary salting near vulnerable areas. Furthermore, it was recommended that all new wells have deeper casing which is cemented into the rock to curtail salt contaminated water transport to the wells in shallow, near vertical fractures.

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Session Classification : Parallel

Track Classification : Topic 8 - Groundwater quality and pollution processes
Hydrological functioning and anthropogenic influence in four shallow ponds by means of daily water balances. Doñana National Park, southern Spain (years 2016-17 and 2017-18).

Daily hydrological balances were made in four shallow ponds of Doñana National Park (southern Spain). Results indicates that Santa Olalla pond is the one receiving a major contribution of groundwater discharge and Zahillo is the one with a lesser contribution. Nevertheless, all the ponds could be classified as through-flow ponds. Distance to a touristic resort and altitude of the pond’s floor have found to be relevant parameters regarding groundwater discharge. In that sense, the ponds located near the resort and higher in altitude receive a minor proportion of groundwater discharge and vice versa. Furthermore, differences in the water balance among year 2016-17 and 2017-18 have also been found in the ponds. Regarding the evolution of the water level and the hydroperiod, the Santa Olalla pond has remained flooded during the entire study period. Zahillo pond has remained 157 days flooded (43% of the year). Taraje pond was flooded 236 days (64% of the year). Finally, Sopetón pond was flooded 231 days a year (63% of the time). In the case of Sopetón, the water is lost - in addition to evaporation and recharge - also through an overflow.

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Session Classification : Poster with refreshments

Track Classification : Topic 6 - Groundwater, wetlands and natural heritage
Water Scarcity in Pacific Island Countries; Experiences in National Water Policy Development.

Monday, 23 September 2019 12:00 (15)

One of the most rational adaptation strategies to global change in Pacific Island Countries appears to be overcoming current challenges by building on the recognised strengths and resilience of island communities, strengthening institutional structures and human resources, while maintaining or enhancing the ecosystems on which island communities depend. Aid agencies and donors have seen the development of national water policy as a key step in adaptation. This work describes experiences in assisting Kiribati, Nauru, Solomon Islands and Tokelau, Pacific countries with varying dependencies on groundwater, to develop national water policies and associated implementation plans. Existing developed world policy frame works, templates and tool kits were of little use in countries were the policy development process is rudimentary or, as in one case, non-existent, and where only one or two people are responsible for water management. Ackoff’s five phases of interactive planning was a useful, easily- understood process for identifying issues and arriving at policy and implementation plans. Because this is an adaptive, iterative process, it is fundamentally important that it is carried out with a whole-of-government and community-representative steering group, particularly with women’s group representatives. A sticking point in the development of attendant national water legislation is the traditional view that land ownership implies ownership of surface and groundwater. While success in policy development is seen as Cabinet approval of policy or plans, successful ownership and implementation of policy is more problematic, particularly in protection of water sources. Long-term mentoring of water agencies has many positive benefits.

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Session Classification : Parallel
Track Classification : Topic 3.1 - Groundwater and water security in developing countries
Climate Change and Groundwater in Low Islands, a surprising resilience

Monday, 23 September 2019 17:00 (15)

The impact of climate change, and particularly rising sea levels on shallow fresh groundwater lenses, is widely regarded as a major challenge to the sustainability of low-lying island countries. Recent research, however, has shown that over 88% of atoll islands in the Pacific and Indian Ocean are counter-intuitively either stable or increasing in land area. During major ENSO events, sea level changes of up to 0.4m above and below normal levels have been observed. Whether atoll reef systems will continue to cope with increasing temperatures and ocean acidification is a critical question. Climate model projections of changes in drought severity and frequency are of generally low confidence because, ENSO events, key drivers of drought in the Pacific, are not well described by climate models. This work reviews both climate change projections and observed impacts on groundwater hydrology in atoll countries in the Pacific. Changes in evaporation requires further work. Greatest vulnerability is to changes in recharge rates, groundwater extraction and island overtopping. Increasing population densities, growing water demands, inadequate sanitation and poor water and sanitation governance are more immediate threats. The best adaptation strategy appears to be overcoming the current challenges by building on the recognised strengths and resilience of island communities, strengthening institutional structures and human resources while maintaining and enhancing the integrity of island ecosystems, as Barnett has concluded, and investing in education and training at all levels.

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Session Classification : Parallel

Track Classification : Topic 2 - Groundwater and climate change
Over the last decade, transboundary aquifers traversing the Mexico-Texas border have generated growing interest by federal institutions on the Mexico side, and state and federal institutions on the Texas side. Notwithstanding this attention, binational efforts to understand, assess, and manage shared groundwater resources remain limited, sporadic and politically sensitive. On the Mexico side, long-standing centralized groundwater governance structures, has created institutional barriers at the local level to the expansion of knowledge and cooperation over these transboundary resources. On the Texas side, property rights related to groundwater resources limit the scope of options available for cooperative management of cross-border aquifers. This paper examines stakeholders’ perspectives on the borderland between Mexico and Texas through 44 surveys and personal interviews. Findings show that stakeholders appear to support a binational groundwater agreement as a means for assuring the sound long-term management of transboundary groundwater resources in the border region; however, the majority of stakeholders also suggest that short-term local or regional arrangements may be preferable over binational agreements as local/regional approaches may be more achievable or realistic. Second, participants identified leadership and individual personalities as key factors for success at the local level, but noted that that such influence had limited sustainability over time and limited regional-systemic effects. Third, the stakeholders indicated that water quality, rather than water quantity, is the main driver of transboundary cooperation and communication efforts in the region. Fourth, participants suggested that failures and successes in groundwater cooperation efforts are based more on fear and political lobbying than on understanding of scientific facts.

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Session Classification : Parallel
Track Classification : Topic 1 - Groundwater assessment and management
Exploration of deep groundwater systems in mega-fans - Example from Northern Namibia

Monday, 23 September 2019 11:45 (15)

Mega-fans are inland riverine deltas occuring in endorheic basins. Their potential as hosts of major aquifer systems has only been recognized rather lately.

The Cubango Mega-fan in Northern Namibia contains three aquifer systems, of which the deep one was only found at the end of the 1990s. Due to its thickness of up to 100 m, its large size and good water quality it is a game changer for the arid North of Namibia. Its spatial distribution and sedimentological background was investigated through core drilling and both geophysical and hydrogeological techniques. Due to the large size of the system, data scarcity is a constant issue affecting the exploration and management of this resource.

Core drilling revealed that the system comprises two major formations of Tertiary age, originating from different source Areas. The cores also contain an archive of the development of the climate of southwestern Africa. The sedimentary background defines the hydrogeological structures.

Groundwater modeling was applied to investigate the rate and location of groundwater recharge. Recharge rates are as low as 2-3 mm/a and limit potential extraction. This needs to be considered in management plans. Remote sensing (satellite radar altimetry) was applied to confirm the recharge areas. They are found in Southern Angola, making it a transboundary aquifer system.

Similar mega-fan systems can be found in other parts of Africa and worldwide. Their hydrogeological potential is high but needs to be investigated in the future. The Namibian case can serve as a blueprint.

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Session Classification : Parallel

Track Classification : Topic 1 - Groundwater assessment and management
Due to constant demographic growth and agricultural growing demand for irrigation water, the inescapable use of groundwater has continuously increased during the last forty years in North African arid and semi-arid regions. Some of these areas are known to comprise worldwide and in many locations huge underground water reserves. This is the case of the large confined aquifers of well-known sedimentary basins such as those of the Sahara desert (North Africa) and Australia (Great artesian basin).

For the sake of integrated groundwater resource management, hydrogeologists and water managers have constantly been worried by the same question that is: what are the evaporative losses and the recharge rates of those huge aquifers?

In addition to the technical and the logistic constraints related to the nature of these regions, they are also characterised by extreme climatic conditions. Whereas conventional techniques often failed, it is surprisingly in such precipitation-poor environments that isotopic tools have proven their efficiency in tackling groundwater issues. Arid zone isotope hydrology has gained more and more importance during the last three or four decades.

The present paper review the contribution of this methodology as applied to the groundwaters occurring in the north western part of the Sahara sedimentary basin (North Africa). Water transfers through the unsaturated zone were investigated in order to compute steady-state groundwater recharge rates and evaporative losses.

Many sites have been investigated during the last twenty years: Béni-Abbès, Chott Chergui, Ouargla, El-Oued in Algeria and Tozeur, Dissa in Tunisia within the framework of separate studies. These investigations aimed at estimating evaporation rates based on unsaturated zone stable isotopes and chloride profiles. This was implemented making use of the deterministic model developed by Barnes and Allison (1982). The evaporation and recharge rates obtained for a 10 m unsaturated soil profile varied between 1 and 40 mm/y. The main objective of the present study, is to gather all these data and to examine how they may be interpreted in terms of recharge rate, evaporation losses can help the water managers of the involved countries to develop or refine appropriate models. This should facilitate the implementation of a trans-boundary integrated management of the shared resources.

Keywords: stable isotopes, chloride, aquifer, modelling, Evaporation, Recharge, Sahara.
The “hydropuls®” Process for Regeneration and Intensification of Wells

Monday, 23 September 2019 12:15 (15)

Dipl.-Ing. Toralf Fischer, Managing Director TLM hydropuls GmbH

“hydropuls®” is a pulse process for the abrupt expansion of highly compressed gas that increases or restores the productivity of wells or helps in the development of wells. The equipment has been successfully implemented in different parts of the world showing that it improves well efficiency and, consequently, well productivity. The technique is currently used in 25 countries around the world, with important customers such Suez, Danone or the Berlin Water Group. The equipment contains a pulse generator that can produce pressure pulse trains using a valve system capable of releasing, in very short times (milliseconds), the energy accumulated in the pulse generator in the form of highly pressurized gas, producing hydraulic shock waves. At the same time a cavitation effect (hollow suction) is caused due to the sudden volume change, which leads to the formation of a “vacuum bubble”, which then collapses and thereby generates a hydraulic “suction wave”. “hydropuls®” is potentially interesting for all well operators and well owners as well as for professionals who have to contend with the problems of well aging.

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Session Classification : Parallel
Track Classification : Topic 3 - Groundwater sustainability and governance
Fresh Groundwater Resources for the Future Generations of Yemen

Unlike most regions in the Arabian Peninsula, Yemen receives appreciable quantities of freshwater due to its position within the migration pathway of the Intertropical Convergence Zone (ITCZ). Heavy rains of around 600 mm/a on average fall over the densely populated western part of the country, denoted here as the Red Sea Zone (RSZ), where about 90% of the population live in major cities or small towns and villages scattered throughout the highland plateau areas. These precipitation events occur mainly as tropical storms during July - September when the southwesterly low-level summer monsoon winds transporting moisture from the Southern Indian Ocean sweep across the country. Heavy rains that can be as high as 1 500 mm/a in the escarpment areas, feed directly the shallow alluvial aquifers in the intermontane areas which, in turn, replenish the underlying deeper and more extensive Cretaceous Sandstones with fresh water. Further down on the coastal areas along the Red Sea, surface water runoff and flash floods descending through major wadi channels percolate into alluvial aquifers extending across the Tihama Plain. It is estimated that a total of about 3.5 billion cubic meter (BCM) per annum of renewable water resources (2 BCM surface water and 1.5 BCM groundwater) is currently generated in Yemen, mainly in the RSZ. This is a substantial volume of freshwater for a country that is predominantly arid to hyper-arid. Yet Yemen has one of the worst water crisis in the world. The very rapid increase in population since the early 1960s continues to put pressure on the availability of freshwater resources, which currently stands at 73 m3/inhab/a. This demographic pressure on the renewable water resources will be compounded by the effect of climate change in the near future since Yemen is particularly vulnerable to climate change. Climate change models predict a steady rise in temperature as well as an increase in variability and intensity of rainfall. This paper looks into the potential effect of climate change in Yemen, both negative and positive. It summarizes the different scenarios of climate change impacts proposed for the country within the context of a probable northward migration of the ITCZ, which would bring more heavy summer rains spreading throughout the entire country. Finally the paper describes the result of recent investigations that shows the occurrence of relatively shallow and unexploited non-renewable groundwater resources of excellent quality in the country, and proposes that these resources should be further explored and developed for providing the future generations in Yemen with fresh water, particularly in the heavily populated RSZ.

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Session Classification : Parallel

Track Classification : Topic 2 - Groundwater and climate change
Identification and delineation of closed ground depressions in order to assess the impact of wildfires on groundwater quality

Thursday, 26 September 2019 16:00 (60)

This work explores the possibility of describing the impact of a wildfire on the quality of groundwater by mapping closed ground depressions on an area of sand dunes. Our hypothesis is that the influence of ground closed depressions, in a landscape that has been affected by fire, is not because they are endorheic areas with preferential recharge (as all the surface of the sand dunes is highly permeable) but because they are traps of in situ fire ashes or fire ashes that have been transported by the wind after the fire. According to the size and weight of the fire ashes, they can be transported by surface creep, saltation and suspension. The particles transported by the first two mechanisms are the most important as they will be directly trapped by the closed depressions while the particles in suspension can travel very far from the fire place and they will become dispersed over a large area and their effect diluted. We have used a methodology that was developed by some of the authors in order to detect karst depressions (Pardo-Igúzquiza et al., 2013) for the identification and delineation of closed ground depressions on detritic materials (sand dunes). The methodology is based on an advanced numerical processing of the digital elevation model (DEM) as proposed by Jenson and Domingue (1988). The DEM used has a spatial resolution of 5 m and a plethora of closed depressions has been found by the analysis. The depth of each depression from its rim is also assessed and thus different morphometric parameters that describe the amount of depressions on the terrain have been calculated. Those parameters are correlated with the water quality measured at sampling points in order to check our hypothesis. The methodology and the results are described in detail in this work.


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Session Classification : Poster with refreshments

Track Classification : Topic 8 - Groundwater quality and pollution processes
Delineation of heat reservoir and thermodynamic equilibrium of thermal waters in the Magumsan area, South Korea

Thursday, 26 September 2019 16:00 (60)

The Magumsan thermal waters located in the southeastern part of South Korea are pumped out from deep wells (about 300m in depth) at temperature between 30.8°C and 49.8°C. In this study, chemical composition, stable isotopic composition such as δ34S, δ18O and δ2H of thermal waters were analyzed to identify their chemical characteristics, meteoric recharge and sulfate origin. The thermodynamic equilibrium between potential reactive minerals and chemical composition of thermal waters was calculated by using the computer program PHREEQC. The geothermometers and 3He/4He isotopic method were used to delineate the heat reservoir and its maximum temperature. The thermal water can be chemically classified into two groups such as low temperature (below 31°C) Na-HCO3 type and high temperature (above 40°C) Na-Cl (SO4) type, which are quite different chemical composition with groundwater of Ca-HCO3 type. The δ34S data of thermal waters shows that the sulfur as a sulfate originates from two different sources such as magmatic pyrite origin and mixed origin of magmatic pyrite and sea water. It can be inferred that the Na, K, Cl and Si of thermal waters were partially supplied by the dissolution of secondary precipitates from hydrothermal alteration through the intrusion of granitic rocks into andesitic rocks. The δ18O and δ2H isotope values of thermal water are congruent with global meteoric water line (GMWL), and show a depletion trend with the increase of temperature, which indicates that a higher temperature thermal water is deeper circulating meteoric water (indicating the higher elevation recharge), and approaches closely into a deep-seated heat source. In three end member mixing diagram of helium, and 3He/4He ratio of thermal waters were plotted along a single mixing line between the atmospheric origin (3He/4He ratio=1.4×10^-6) and the line representing helium origin with crustal contribution of 97.21-96.32% (3He/4He=0.34×10^-6). The positive correlation between 4He content and temperature of thermal water and dominant crustal-origin helium contribution strongly imply that thermal waters in the Magumsan area have been affected by the heat source generated from the decay of heat-producing radioactive elements in the crustal rocks. It is estimated that maximum heat reservoir temperature amounts at 165 ℃ by the geochemical geothermometers. The water-mineral equilibrium evaluation in Na-K-Mg system shows that thermal waters is under partial equilibrium with potential reactive minerals.

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Session Classification : Poster with refreshments
Track Classification: Topic 8 - Groundwater quality and pollution processes
Isotopic and geochemical evidence of groundwater origin and salinization in multi layered coastal aquifer of India

Monday, 23 September 2019 12:30 (15)

The origin and salinization of groundwater in multi layered coastal aquifer of Sankaraparani river basin, India was studied using isotopes and geochemical signatures. Groundwater in this region occurs in shallow unconfined and deep confined aquifers. The shallow aquifer comprises of Quaternary Alluvium whereas the deeper aquifer comprises of Tertiary sandstone. Groundwater sampling from different aquifers was carried out once in three months since June 2017. Parameters such as pH, electrical conductivity, oxidation reduction potential and temperature are measured in the field whereas the concentration of major ions (Ca, Mg, Na, K, Cl, SO4, HCO3) and stable isotopes (δ18O and δD) are measured in the laboratory. Geochemical signatures such as electrical conductivity, sodium chloride ratio, base exchange index and seawater mixing index indicate that upper aquifer is affected by seawater intrusion whereas the lower aquifer contains fresh groundwater. The isotopic composition of groundwater shows that in the upper aquifer δ18O ranges from -6.8‰ to -1.3‰ and δD ranges from -43.1‰ to -13.8‰ whereas in lower aquifer, δ18O and δD ranges from -5.96‰ to -3.59‰ and -39.29‰ to -23.07‰. Enriched δ18O and δD is observed in few regions near the coast. δ-excess in the groundwater of upper and lower aquifer ranges from -3.7‰ to 10.9‰ and -1.03‰ to 20.13‰. Higher δ-excess and depleted δ18O shows that evaporation process dominant in this region. The relationship between δ18O and δD compared with the local meteoric water line shows that the groundwater in this region is the meteoric origin. Groundwater samples near the coast with a higher concentration of chloride and enriched δ18O indicate seawater intrusion. The origin of groundwater in the upper and lower aquifers is from rainfall recharge and the groundwater in the upper aquifer has a high concentration of ions due to seawater intrusion.

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Session Classification : Parallel

Track Classification : Topic 8 - Groundwater quality and pollution processes
Geochemistry of trace elements and microbial assessment in groundwater contamination and soils (South-eastern Nigeria)

Waste derived from anthropogenic activities like automobile industries and households contain toxic elements contaminating water bodies and soils, thereby endangering human health in developing countries like Nigeria. Some rural parts of Anambra State in South-eastern region of Nigeria, supply water from boreholes and hand-dug wells as common groundwater abstractions. The aim of the study was to investigate the deteriorating water quality and soils within densely populated area (slum) of automobile junk market in Obosi, and residential (in Onitsha) in Anambra, South-eastern Nigeria. An intensive seasonal phyiscochemical and hydrogeochemical assessment were carried out to examine the concentration of heavy metals in groundwater and soils, and determine the quality of the water for drinking and other domestic purposes. In addition, the fecal contamination of the water was assessed by evaluating for the presence of fecal coliforms using standard microbiological methods. Forty groundwater samples were collected in dry and wet seasons from boreholes and hand-dug wells. The samples were subjected to Atomic Absorption Spectrometry using standard field and laboratory techniques. The groundwater is slightly acidic to neutral, soft to moderatly hard. Some of the toxic and trace elements (Fe, Cu, Ni, Zn, Mn, Pb and Cd) were found to be more than the desirable levels in drinking water (WHO guidelines, and the Nigerian Standards). There was absent of fecal but lower count (1.0 x 10^2 to 2.5 x 10^3cfu/ml) of total coliform was observed. Higher heavy metals content in ppm (Pb and Cd varied 0 to 1.80 and 0 to 7.38 respectively, and Fe, Cu, Ni, Cr, Zn, Mn) was found in the soil (and permeable). Statistical results gave significant correlation differences (at 0.05) between EC and nitrate, EC and TH, BOD5 and DO, and several other elements. The Contour maps for the trace elements displayed the spatial distribution (pollution pattern) and point source of contaminants. The study helps in the understanding of the chemistry of groundwater for long monitoring and management for the local community, as well as adopts remedial measures and controls pollution.

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**Session Classification**: Parallel

**Track Classification**: Topic 8 - Groundwater quality and pollution processes
Use of 16S rRNA Sequencing Analysis on Bacteria in Well-Water to Identify Groundwater Recharge Sources

Monday, 23 September 2019 15:45 (15)

In this study we use a novel approach to evaluate the source(s) of nitrate contamination in a complex coastal environment. Given a low hydraulic gradient, tidal influences, and highly permeable sand and gravel aquifers, a conventional investigation was unable to discern whether a farm was the source of nitrate contamination in surrounding domestic wells. Alternatively, other potential sources of nitrate may be related to local septic fields and household fertilizers. As a novel approach, we evaluated the use of bacteria communities as a groundwater tracer. Bacteria community composition is controlled by measurable environmental factors such as water quality and soil conditions. Additionally, bacteria can be carried by water from source areas into major groundwater flow pathways as a biological colloidal particle. Understanding bacteria transport and biogeography coupled with new rapid techniques for characterizing bacteria populations through 16S rRNA sequencing have made bacteria useful as a practical groundwater tracer tool. In this study, groundwater samples were collected from eight domestic wells and two farm wells. Bacterial DNA was extracted from the well-water samples and underwent 16S rRNA sequencing on an Illumina MiSeq Sequencer. The relative abundances of bacteria groups present in each sample were determined and used to evaluate population similarities and differences. Based on a Bray-Curtis Non-metric Multidimensional Scaling analysis, it was found that the bacteria community structure associated with each well could be divided into three distinct groups. The bacteria communities in the farm wells were found to be distinctly different from the domestic wells which suggests that the farm was not the source of nitrate in the domestic wells. The bacteria communities among the eight domestic wells could be further divided into two distinct groups. It is likely that the bacteria community structure associated with the two domestic well groups is related to the proximity of each well to two surface water bodies; in this case, a brackish river and tidal salt marshes. This study demonstrates the use of bacteria communities as a means to evaluate recharge sources to groundwater. The results of this study also provide a foundation for future work involving this novel method of using bacteria as a groundwater tracer.

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Session Classification : Parallel

Track Classification : Topic 5 - Tools, methods and models to study groundwater
Earth and atmospheric subsurface tidal analysis - A passive approach to quantify groundwater system properties

The effective management of confined subsurface systems is often hampered by a lack of hydraulic parameter data for reliable numerical modelling. The data available is often spatially and temporally sparse due to the extensive labour and set up costs required for methods such as aquifer pump tests to acquire either hydraulic conductivity and/or specific storage. This problem could be addressed by applying Tidal Subsurface Analysis (TSA) to routinely collected water level monitoring pressure data. The method utilises the naturally induced strains from globally occurring Earth and atmospheric tides on the Earth’s crust. Earth and atmospheric tides induce multiple harmonic oscillations in groundwater pressure data, which are able to be separated using signal processing techniques into the individual tidal components of various magnitudes. These components can be compared to the synthetically produced tidal or loading potentials and analysed for shifts in phase and difference in amplitude responses. These can then be used to determine storage changes and hydraulic diffusivity, thus also permeability. Here, we present principles for TSA and provide an overview of the state-of-the-art research using TSA methods for aquifer characterisation, as well as for determining confinement including a method for deriving a quantitative measure of semi-confinement.
Permanently operating mathematical model of a group of groundwater well-fields in Kazakhstan as the basis for groundwater’s monitoring and management

Monday, 23 September 2019 16:00 (60)

Seven deposits of groundwater, which are located in the slope side of the Caspian depression in the Lower Cretaceous Albian aquifer complex, were investigated and put into operation to provide drinking and industrial water supply for oil and gas production facilities. The well-fields are located within the plateau, which was dissected by valleys of rivers and streams. The aquifer complex is composed of different-grain sands with interlayers of clay with a total thickness of about 200 m. It is confined or unconfined on different areas. Its groundwaters are interconnected with river waters in some places. The groundwaters of the aquifer complex are fresh or brackish with mineralization of $0.2 \div 3.2$ g/l. The estimated volume of the exploitable groundwater resources of seven well-fields reaches 1.03 m$^3$/s.

Groundwater intakes are operating under conditions of their mutual influence. In addition, the abstraction of the brackish groundwater for production and technical purposes can attract the fresh groundwaters to these industrial water intakes. But the use of fresh drinking water for production and technical water supply is prohibited by the legislation of Kazakhstan.

Thus, a rational exploitation of these groundwater well-fields, taking into account environmental limitations, is an actual problem.

An observational network of groundwater monitoring has been created in all groundwater well-fields. To assess and predict the state of the well-fields and the aquifer complex as a whole, in 2014, in the ModFLOW Flax software, a permanently operating mathematical model (POM) of seven groundwater fields was built and put into operation. POM is operated to ensure promptly reliable assessment and predictive information on changes in the hydrogeodynamic and hydrogeochemical state of water intakes and of the Albian aquifer complex as a whole.

The result of solving the geofiltration and geomigration tasks on the POM allow anticipating the development of undesirable hydrogeodynamic and hydrochemical processes, to develop recommendations for optimizing the monitoring network and the regime of groundwater well-field’s abstraction to eliminate the risks of special hydrochemical situations for the industrial groundwater supply on the oil and gas production facilities. This can significantly reduce the risks of inadvertent use of fresh groundwater for production and technical purposes and provide the sustainable development of the oil production sector.

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Session Classification: Poster with refreshments
**Track Classification:** Topic 5.3 - Advanced modelling tools for subsurface hydrology: from the vadose zone to deep environments
The aim of this work was to develop the exact groundwater flow model within a confined aquifer. We argued that, the Theis groundwater flow model is an approximation of the real formulation of the model as Theis removed some components of the equation to have a simple model. Initially, we derived an exact groundwater flow equation for a confined aquifer so as to include all high order terms that were removed by Theis and also to take into account the assumptions that were used during the derivation of the groundwater flow by Theis. Thereafter, we proved that the new groundwater flow equation has a unique solution. We then derived a new numerical scheme for a singular partial differential equation that combines the Mellin transform and the Lagrange approximation of a continuous function. The Mellin transform was used to remove the singularity in the newly developed exact groundwater flow equation for a confined aquifer. The equation became ordinary, wherein we used the Adam Bashforth method to the ordinary differential equation in the Mellin space. The inverse of Mellin was then used to get the exact numerical scheme in real space. We present the stability analysis of the new numerical scheme using the von Neumann method. Lastly, numerical simulations using experimental field data are presented. Our solution is compared to that of Theis. Our simulations show the importance of the scaling factor which was removed from the Theis groundwater flow equation. The simulations also show that the change in drawdown depends on the scaling factor.

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Session Classification : Parallel

Track Classification : Topic 5.3 - Advanced modelling tools for subsurface hydrology: from the vadose zone to deep environments
ASSESSING COASTAL AQUIFER VULNERABILITY TO SEAWATER INTRUSION USING GALDIT METHOD: APPLICATION TO THE OULJA COASTAL AQUIFER, SAHEL DOUKKALA, MOROCCO

Monday, 23 September 2019 12:30 (15)

The Oulja Coastal Aquifer is part of Sahel Doukkala System Aquifer, is one of the main groundwater coastal aquifers in Morocco. It covers about 160 km² and has a significant role in satisfying water needs for agriculture and potable water supply in the region. Over years, the need for agricultural water has increased, overexploitation of groundwater resources can put their quality under stress. It could be based on rapid disturbance in groundwater level leading to saltwater intrusion in this coastal aquifer.

To evaluate extent of the threat of the seawater intrusion. The present study is an attempt to map the vulnerability of the groundwater in Oulja Coastal Aquifer of against this intrusion by means of modeling coupled with GIS. The methodology used in the study consists of assessment of vulnerability using GALDIT method, is based on the most important factors controlling seawater intrusion, that is, four intrinsic hydrogeological parameters, one spatial parameter and one boundary parameter including Groundwater occurrence (aquifer type), Aquifer hydraulic conductivity, depth to groundwater Level above the sea (hydraulic head), Distance from the shore, Impact of seawater intrusion and aquifer’s Thickness.

Assigning each map an appropriate weightages and ratings, and the overlaid of the six thematic maps has allowed to produce vulnerability map. The result of the study indicates a high vulnerability to seawater intrusion due to excessive groundwater withdrawals, especially in the Oulja coastal zone. This vulnerability is more witnessed in the South near the Oualidia Lagoon than in the North of the studied area. The outcomes of this study provide useful insights on effective groundwater management for the Oulja Coastal Aquifer.

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Session Classification : Parallel

Track Classification : Topic 5 - Tools, methods and models to study groundwater
Numerical assessment on the impact of water table decline on phreatophytes in arid regions

Friday, 27 September 2019 11:15 (15)

Water demands have been increasing for the recent decades, leading to a continuous decline of water table in many parts of the world. As a result, phreatophytes (groundwater-dependent plants) in these regions are threaten by the increase of water table depth induced by groundwater abstractions. Quantitative assessment of the impacts of groundwater level decline on phreatophytes in hyper-arid and arid regions is key to sustainable groundwater management. Although relationships between the responses of phreatophytes to water table decline were developed by previous studies, these relations are site-specific. A general model describing the response of phreatophytes to falling water table across (hyper-) arid regions is not available. In this study, we aims to develop a general model that enables to predict such response across arid regions. A variable saturated flow model, HYDRUS-1D, was used to numerically assess the controls of depth to water table (DWT) and mean annual precipitation (MAP) on transpiration of groundwater-dependent vegetation in (hyper-) arid regions of northwest China where MAP ranging from 15 mm to 198 mm. An exponential decrease is found for the normalized transpiration (a ratio of transpiration at a certain DWT to transpiration at 1 m depth, $T_a$) with increasing DWT, while a positive linear relationship is found between $T_a$ and MAP. The sensitivity analysis show that the model is insensitive to parameters, such as saturated soil hydraulic conductivity, water stress parameters and rooting depth, indicated by an insignificant variation (less than 20% in most cases) under ± 50% changes of these parameters. Based on these two relationships, a general model was developed to forecast the response of phreatophyte transpiration to groundwater drawdown for (hyper-) arid regions using MAP only. The $T_a^*$ estimated from the model was reasonable comparing to the published measured values.

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Session Classification : Parallel

Track Classification : Topic 6 - Groundwater, wetlands and natural heritage
Prediction of the groundwater level is needed for management of groundwater resources or monitoring in specific sites such as pollution areas. Neural networks are powerful tools for estimating or predicting the groundwater levels in hydrology. There are various kinds of architectures in neural networks such as Artificial Neural Network (ANN), Deep Neural Network (DNN), Long Short Term Memory (LSTM), and Stacked Long Short Term Memory (S-LSTM). These models were applied to predict the groundwater levels in riverside areas where much of groundwater is consumed. Model performances from each neural network model were obtained to be compared with each other. While the ANN model was the most basic neural network, it had a range of RMSE errors from 0.0331 m to 0.0562 m. LSTM showed the best model performances among the four neural network models. Additionally, deeper networks like DNN and S-LSTM did not always show better performances than simple networks, which can imply that the most complex model is not necessarily the best network. Because various neural network models give their efficiency differently according to the type of data or system, determination of proper network would be important when machine learning techniques are applied for prediction of the groundwater level.

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Session Classification: Poster with refreshments

Track Classification: Topic 5.3 - Advanced modelling tools for subsurface hydrology: from the vadose zone to deep environments
A unique case of water drawdown in deep artesian wells with a very high well-loss component

Tuesday, 24 September 2019 16:00 (60)

The water drawdown in pumping wells in a fully penetrated confined aquifers is defined by the following equation (Jacobs, 1947):

\[ S = BQ + CQ^2 \]

where \( S \) is the drawdown inside the well (L), \( Q \) - pumping rate (L^3/T), \( B \) - aquifer (laminar) head-loss coefficient (T/L^2) which is attributed to the aquifer and varies with pumping duration, and \( C \) - nonlinear (turbulent) well-loss coefficient (T^2/L^5) caused by resistance to water flow into and inside the well. The common method to analyze the two components of the drawdown - \( BQ \) (aquifer-loss component) and \( CQ^2 \) (well-loss component) is by a step drawdown test using the graphical Hantush-Bierschenk solution (Kruseman and de Ridder, 1990). The parameters determined by this test include hydraulic values such as transmissivity, and several performance and engineering values, such as aquifer-loss, well-loss, specific capacity and well efficiency (the ratio of the aquifer loss to total/measured drawdown). In wells that are technically well-constructed and with no clogging, the \( CQ^2 \) term is expected to be low and most of the drawdown is due to the aquifer’s characteristic as represented by the \( BQ \) term.

Step drawdown tests were conducted in two deep wells in the northern part of Israel: HT-1 (878 m) and SH-2 (1,397 m). The two wells are located 5.2 km apart, and tap two different fractured Jurassic limestone formations. Well SH-2 is perforated along 196 m at its lower part, while well HT-1 was left as an open hole (68 m). The aquifers in both wells are confined with water heads of 12-13 atm. above surface.

The artesian discharges measured at the end of the drilling was ~1,400 and ~1,000 m^3/hour in wells HT-1 and SH-2, respectively. During subsequent production, discharge rates decreased as the artesian pressure dropped. Despite the high artesian flows and according to the tests, most drawdown in both wells is due to well-loss (81-92% and 96-99% in HT-1 and SH-2, respectively). Furthermore, their well efficiency is very low (9-18% and 1-3.5%, respectively). However, according to Walton’s (1962) classification of the degree of well deteriorations, the relatively low \( C \) values in both wells (962 and 1,744 sec^2/m^5, respectively) imply properly designed and developed wells. Since there is no clogging in the wells, we believe that the combination of great depths and long and fast artesian vertical flow to the surface in narrow casing are the main reasons for the unique high \( CQ^2 \) in these high discharge wells. The sharp decrease in the specific capacity (Q/S) over the wide range of the applied pumping rates during the tests (36.5 to 10 m^3/hour/m in HT-1 and 21.8 to 11.6 m^3/hour/m in SH-2) confirm this interpretation.

We seek to learn whether such extremely high \( CQ^2 \) values were encountered in other production wells worldwide.

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Session Classification : Poster with refreshments
Track Classification: Topic 5 - Tools, methods and models to study groundwater
Rainfall influence on acid discharges from an anthropogenic mine aquifer generated by sulfide mining (SW Spain)

Thursday, 26 September 2019 16:00 (60)

The Iberian Pyrite Belt (IPB) located in SW Spain is one of the largest massive sulfide deposit concentrations in the world. Large-scale exploitation of these deposits took place since the second half of the XIX century to the end of the XX century. As a result, there are numerous derelict mines within the drainage basins of the Tinto and Odiel rivers, where intense sulfide oxidation processes lead to the formation of extremely acid lixiviates, causing the pollution of the aquatic ecosystems. This study analyzes the response to rainfalls of an acid discharge from an old derelict underground gallery at Poderosa mine, which exploitation ended in 1924. This discharge constitutes the only outflow from a small anthropogenic aquifer caused by mining. Extremely low pH values (around 2), high electrical conductivity (close to 10 mS/cm) and concentrations of Fe (around 2 g/L) and other toxic elements are commonly found. The gallery discharge is relatively constant through the year (from 0.5 to 2 L/s), although flows higher than 10 L/s are recorded after intense rainfall episodes. An autosampler and a Parshall flume equipped with a continuous level logger were set up at the outlet of Poderosa mine adit from October to December 2016. Results obtained during this high-resolution sampling are shown in this study.

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Session Classification: Poster with refreshments

Track Classification: Topic 8 - Groundwater quality and pollution processes
On the use of ELLAM for seawater intrusion in fractured porous media

Tuesday, 24 September 2019 16:00 (60)

The topic of density driven-flow in fractured porous media has long been widely attracted an attention of researchers for coastal environment management and protection. The complex phenomena involved such process are fundamental for seawater intrusion in coastal area, flow through salt formations and saltwater upconing under freshwater lenses. In order to protect the fresh groundwater and the surrounding environment, there is a need to predict the location and the movement of the saltwater interface. The complexity of seawater intrusion problems which generally cannot be analytically solved has risen a high interest on the development of advanced numerical models for density-driven flow as this process is governed by highly coupled, nonlinear, partial differential equations derived from combination of momentum and mass conservation laws.

The objective of this work is to implement, for the first time, the combination of the Mixed Hybrid Finite Element (MHFE) and the Eulerian-Lagrangian Localized Adjoint Method (ELLAM) to solve seawater intrusion problem in fractured porous media. The MHFE method, which is well known to ensure an accurate and consistent velocity field, and the ELLAM, which is efficient for large time and large scale problem, are coupled to solve the variable-density flow equation. A Discrete Facture Model (DFM) is used to correctly represent fracture embedded in the porous matrix. This model is highly accurate as it can represent fractures explicitly without any simplification. However, numerical solution of this model with classic numerical methods can lead to numerical artifacts that can affect the solution to various degrees and in consequence the physical behavior of the system. This problem can be avoided with our implementation of a high accurate solution based on the Eulerian-Lagrangian Localized Adjoint Method. The performance of our developed model is tested and compared against the Eulerian Discontinuous Galerkin method based on benchmarks inspired from the Henry problem extended to fractured test cases. The results show that ELLAM remains accurate and efficient as this method overcomes the Courant-Friedrichs-Lewy (CFL) restriction.

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Session Classification : Poster with refreshments

Track Classification : Topic 5 - Tools, methods and models to study groundwater
Characterization of an acid spring with extreme conditions of a dump at the Tharsis sulfide mines (SW Spain).

Friday, 27 September 2019 09:40 (15)

The mining district of Tharsis is located on the Iberian Pyrite Belt (IPF), which is rich in massive polymetallic sulphides. It has been exploited for almost 5,000 years, although large-scale exploitation began in 1866 and continued until 2001, when it completely ceased. Sulfides on contact with the atmosphere generate an acid leachate known as acid mine drainage (AMD) containing high concentrations of toxic metals such as Fe, Zn, Cu, etc. As a result of mining, 5 large open pits have been generated, 4 of them flooded with acidic water, and huge areas of dumps, where numerous acid leachates are generated. The largest permanent discharge of acid water from the Tharsis area, and probably also from the entire Iberian Pyrite Belt, is located at the base of a 66 Ha dump and up to 75 meters high. Its flow varies between 2.2 and 6.3 L/s (percentiles 10 and 90), with a maximum of 12.6 L/s in a period of heavy rains. It has average pH values of 2.4, electric conductivity of 21.9 mS/cm, Eh of 577 mv and a thermal character because the oxidation reaction of pyrite is exothermic, with an average temperature of 25ºC. Likewise, it has very high concentrations of SO4 (31 g/L), Fe (4.6 g/L), Al (1.4 g/L), Zn (0.5 g/L) and many other toxic elements. Therefore, the polluting load of this spring is very high and represents an important source of acidity to the Alcolea reservoir (246 hm3 capacity), which is currently under construction. The water quality of this reservoir is uncertain due to the numerous acidic contributions it will receive. In this paper we analyze the results of the periodic control of this acid upwelling between February 2017 and March 2018, with a periodicity between fortnightly and monthly, especially its response to rainfalls and the evolution of the physicochemical parameters, the concentrations of metals and of the pollutant load.

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Session Classification : Parallel
Track Classification : Topic 8 - Groundwater quality and pollution processes
Unlocking the mysteries of the Diquini Tunnel,
Haiti’s largest supply of water

Thursday, 26 September 2019 11:15 (15)

The Diquini Tunnel is the largest single source of water supply in Haiti, accounting for 24-percent of the water produced for the metropolitan water system of Port-au-Prince. The 1.5-km tunnel was conceived during the United States occupation of Haiti in the early 20th Century, and was completed in 1940 by the J.G. White Engineering Corporation. The tunnel penetrates the Eocene-age Massif de la Selle limestones, targeting a fault and karst zones to produce a gravity-fed water supply for the city. Tunnel flows range from 11,085 to 73,265 m³/day, averaging approximately 28,000 m³/day.

A reconnaissance and forensic research effort was undertaken to characterize the hydrology of the tunnel and better understand the origin of its flow and its relationship with local and regional groundwater and surface water systems. The study included field mapping, terrain assessment using recent LiDAR data, and laboratory analysis of the tunnel water for physiochemistry, stable isotopes, chlorofluorocarbon (CFC), and sulfur hexafluoride (SF6).

Several decades of historical monitoring data were uncovered and synthesized with the new results to bring light to the complex hydrology of the tunnel, and the importance of large recharge events and El Niño-Southern Oscillation cycles in maintaining productive tunnel flows to serve the Port-au-Prince metropolitan area. The findings of the study also provide important insights for groundwater development and management related to the Massif de la Selle aquifer.

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Session Classification : Parallel

Track Classification : Topic 7 - Karst Hydrogeology
Improved representation of regional groundwater flow in the Hertfordshire Chalk (UK) by merging four existing regional groundwater models.

The Environment Agency required a single regional groundwater model to better represent flow in the Chalk aquifer in Hertfordshire (United Kingdom). Previously, four adjacent regional groundwater models were used; the South-West Chilterns, Vale of St. Albans, Cam and Bedford Ouse and Rib Ash Stort models. A single groundwater model reduces the impacts of boundary effects at the model joining locations and ensures a consistent approach to Chalk modelling in the area. The completed Hertfordshire model will be used to inform regulatory decisions, assess the impacts of abstraction on water bodies under the Water Framework Directive, inform Source Protection Zone delineation and inform water company source investigations.

Bedrock geology in the study area comprises the White Chalk and the Grey Chalk subgroups, which are confined by the Lambeth Group and Thames Group in the south-eastern area of study. The study area includes major rivers such as the River Thames, the River Lee, the River Colne and their tributaries. Karstic streams are present in the River Colne catchment, causing water to flow via sinkholes eastwards into the River Lee catchment. The model simulates a total of 1,248 groundwater abstractions and discharges with a total fully licensed abstraction volume of 1,170Ml/d. Approximately 96% of groundwater abstracted from the Hertfordshire Chalk between 2011 and 2015 was for public water supply.

A new recharge model was developed using the 4R (Routing of Rainfall to Runoff and Recharge) code (Entec UK Ltd, 2006) to simulate recharge and the runoff component of surface water flow. A modified version of the U.S Geological Survey groundwater model (MODFLOW-96) which allows variable conductivity with depth was used to simulate groundwater flow in the study area. Construction of the Hertfordshire groundwater model was undertaken by merging the component models into a single MODFLOW-VKD model, with an active model area of 4,060km2, making it one of the largest groundwater models in the UK. Component model parameters were retained, where appropriate. To ensure consistent routing and as a product of the new recharge model and new LIDAR data, a new stream file was produced.

The Hertfordshire Chalk model was calibrated to 232 observation boreholes and 34 stream gauging stations in the area. Final calibration resulted in 73% of gauging stations showing either an improvement on the component model or simulating average flows within a 15% difference to the average observed flows. Almost all locations show a good calibration to stream flows; where the Hertfordshire model does not improve on the component model, the model results are still considered good in the context of a regional Chalk model. The model was deemed fit for purpose in all but one catchment, the River Beane catchment, though groundwater levels are simulated better than the component model.

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Session Classification: Poster with refreshments

Track Classification: Topic 5.4 - Innovative approaches for understanding groundwater flow systems
CLUES-GW: A Simple Coupled Steady State Surface-Groundwater Model for Contaminant Transport

Friday, 27 September 2019 10:10 (15)

Increasing nitrate-N (N) concentrations in fresh waters is impacting adversely on New Zealand’s environmental and economic resources. We developed a simple catchment model, CLUES-GW, that provides mean-annual contaminant load and concentration estimates for surface water. CLUES-GW represents an extension of the existing CLUES, the Catchment Land Use and Environmental Sustainability model (Elliott et al. 2016)*. CLUES-GW includes up to two groundwater reservoirs under each surface water sub-catchment. The groundwater reservoirs exchange water with the adjacent (groundwater) reservoirs. The shallow reservoir also exchanges water with the surface-water streams. The runtime of the model is approximately 4 seconds, and so the quick runtime allows extensive model calibration, uncertainty and scenario analyses. The model was applied to two case study catchments to investigate N transport. The first catchment, Hauraki is located within the Waikato region of New Zealand and consists of 7,295 sub-catchments. Monte Carlo parameter conditioning from 10,000 parameter realisations was used to identify the best 200 ‘posterior’ parameter sets. The posterior parameter distributions were used to examine the N loads and concentrations at key locations under the current N loading dynamics and a hypothetical future scenario of 20% reduction in N loading. The second catchment, Mid-Mataura in the Southland region of New Zealand, is relatively smaller and has 1,535 sub-catchments. The model was calibrated using PEST software against measured river flows, and N loads and concentrations. An approach was developed to disaggregate model outputs, of mean-annual contaminant loads and concentrations, to daily timesteps using a rating-curve relationship between measured flows and concentrations. The calibrated model output along with the relationships developed for disaggregation were used to develop daily N concentration timeseries using flow data. The daily N concentration timeseries will be used as a management tool to assist with land and water management within the catchment.


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Session Classification : Parallel

Track Classification : Topic 8 - Groundwater quality and pollution processes
Understanding land use change impacts on freshwater using integrated surface water-groundwater modelling

Tuesday, 24 September 2019 16:00 (60)

Understanding the age distribution of water at key locations in a catchment is crucial to understanding water-quality dynamics. Current trends in water quality may be a combination of both historical land use change and lag times to a point of interest in the catchment. To assess the temporospatial relationship between Nitrate-N (N) concentrations in fresh waters and changes in intensive agriculture in the Upper Waikato catchment (New Zealand), an integrated surface water-groundwater MODFLOW-MODPATH model was developed. The model provided the estimation of water travel times from different locations in the catchment to its end point (surface water) using particle tracking. The model simulates steady-state saturated flow and particle transport, and includes the Waikato River and all the major tributaries in the catchment (using MODFLOW’s STR package). This integrated surface water-groundwater model was calibrated against measured groundwater levels, river gains and losses, and water quality observations of N and tritium. To address the insufficient tritium data availability in some areas, a relationship between SiO2 concentrations and mean resident time (MRT) using measured tritium was used.

A particle was released into the water-table at the centre of each (uniform) model cell, and the travel time for each particle to reach its end-point was calculated. The mean age and age distribution of water at different locations was estimated from the collection of particle travel times contributing to the end point. The MRT for water contributing to the average flow at tributaries was estimated between 5 to 101 years, with an average of 51 years. The model results showed that MRT alone can be misleading, and it is important to also identify the age distribution of water discharged from sub-catchments. Approximately two thirds of the flow from most sub-catchments had ages that were less than the MRT. This is because MRT distribution is skewed by a few contributions from very long travel times. The model also suggests that travel times from areas that are subject to more recent land-use intensification can differ to travel times for the catchment as a whole. Therefore, it is important to consider both the historical and spatial distribution of land use change. This work demonstrates how groundwater modelling can be used as an effective tool for unravelling the effects of variable lags in the contaminant loads from historical land use changes when investigating current trends in water quality.

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Session Classification : Poster with refreshments

Track Classification : Topic 5 - Tools, methods and models to study groundwater
Irrigation developments in northern Australia have had a checkered history due to many different factors – primarily the highly variable surface water sources and the poor economics of many of the crops grown. With the aim of improving the security of the water sources, the technical and economic feasibility of managed aquifer recharge (MAR) for irrigation development in selected regions in Northern Australia has been assessed. The technical assessment involved matching the MAR method with the varying hydrogeological environments to identify the most cost effective approach. This involved the use of recharge weirs for shallow aquifers and relatively shallow injection bores where deeper confined aquifers were the target. The source water is a small percentage of the wet season surface water flows. Specific characteristics of Northern Australia, namely the cost of transporting water, very high evaporation rates, the variability of wet season rainfall and the need for scalable water resource developments, make MAR an attractive alternative to large dams. So called “mosaic” irrigation, whereby many relatively small scale MAR based irrigation schemes are dispersed across northern Australia is the preferred model for development. Several sites in Western Australia and the Northern Territory were studied in detail to assess their technical and economic potential. Capital and operational costs were determined for various schemes and the levelized cost of the MAR schemes typically varied from A$120 to A$150/ML. The economic return from various crop types was determined and this showed that traditional fodder production for beef cattle production was not economic, whereas a variety of other crops were economic. This work showed that MAR based schemes are technically feasible in many locations, but choosing the most economic method and crop type requires careful judgement.

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Session Classification : Parallel
Track Classification : Topic 3 - Groundwater sustainability and governance
Abandoned coal mines and groundwater pollution: A case study in S. Pedro da Cova, N Portugal

Thursday, 26 September 2019 16:00 (60)

The mining industry causes substantial environmental impacts with significant changes to the landscape and the disturbance of subsurface conditions. Nowadays, these activities must comply with rehabilitation plans, which aim the mitigation of the mining environmental effects. However, abandoned mines that used exploitation methods that are currently considered inadequate had, and continue to have, devastating effects on nature and society.

The S. Pedro da Cova coal mine is located in the north of Portugal and was deactivated forty years ago. A neutral mine drainage, rich in iron (Fe) and manganese (Mn), is still being produced and continuously discharged in local streams (Ribeiro de Murta and Rio Ferreira) and in surrounding lands through agricultural irrigation practices.

Groundwater from mine drainage galleries and from a spring free from mining influence were analysed during six campaigns, from April 2017 to February 2019, for a range of chemical constituents such as electrical conductivity, pH, turbidity, PO4\(^{2-}\), SO4\(^{2-}\), NO3\(^{-}\), NO2\(^{-}\), NH4\(^{+}\), F\(^{-}\), Cl\(^{-}\), Na, Ca, Mg, K, B, CN, Zn, Cu, Cd, Cr, Fe, Mn, Al, Ni, Pb and As.

The impacted waters have a hydrogeochemical facies of Ca-Mg-SO4, with high metal content, especially iron, manganese, nickel and arsenic that may cause various health hazards such as cancer. Mine effluents are characterized by a temperature higher than the mean annual air temperature, as well as by a relatively high fluoride content, pointing to a mixture between groundwater circulating in the shallow rock massif, along the mine galleries and wells, and thermomineral water following through deeper circulation paths.

The chemical status of groundwater was also assessed through the Water Pollution Index (WPI) calculation by comparing the results with the legal guideline values for drinking water and water for irrigation purposes.

As the overall quality of groundwater from mine drainage galleries revealed severe contamination it is very important to raise awareness for rapid intervention in the area, since the mine is located near a population centre and social infrastructures, and to mitigate impacts on adjacent agricultural lands.

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Session Classification : Poster with refreshments
Track Classification: Topic 8 - Groundwater quality and pollution processes
Geothermal use of old flooded mines: from a risky trial-and-error approach towards challenging predictive simulations

In urban areas, flooded abandoned mines could be used for shallow geothermal purposes. Such aquifer thermal energy storage (ATES) systems, using heat-pumps and an open loop with a groundwater pumping and re-injection doublet, are highly challenging and uncertain with risks undermining the ultimate feasibility. The true geometry of the interconnected network made of old open galleries and shafts can be highly complex and partially unknown/forgotten. Indeed, high-velocity water flow is expected in this network, while low-velocity groundwater flow occurs in less permeable fractured and porous rock massif. For the latter, hydraulic conductivity values have been significantly increased by mining exploitation. Logically, hot water is pumped in the deep parts of the open network, and cold water can be re-injected in the shallower parts (i.e. in shallower galleries or fractured rocks). A seasonal inversion could be planned for building cooling during the hot season.

So far, those who have successfully moved to such a heat production have adopted a risky strategy that can be qualified as a trial-and-error procedure. Indeed, after some time, a cold water breakthrough is observed as mixing with the pumped deep hot waters. In fact, this strategy needs to continually adapt the project by integrating several pumping/injection wells, seasonal variations, and even a further integration of other renewable energy sources in a local smart grid. This ends up with very significant investments that are rarely planned at the beginning of the project.

Another approach could be to involve more accurate hydrogeological characterization of the old mined zones for detailed simulations of the groundwater flow and the associated temperature evolution in pumping zones. The challenge is huge because characterization and numerical issues are to be solved. Added to the often unknown complexity/heterogeneity of the galleries network conjugated to those of the mined geological formations, variable density water flow and coupled heat transport must be taken into account using a dedicated software allowing to simulate a combination of high-velocity ‘pipe-like’ water flows (in the galleries) and porous/fractured groundwater flow (in the rock matrix). An example of a simplified but realistic situation is given showing numerical results with the differentiated temperatures as a consequence of heat/cold propagation in the galleries, shafts and the fractured rocks. This kind of numerical simulations allow to anticipate the temperature changes affecting the future (short-, mid-, and long-term) efficiency of the geothermal system as well as possible environmental impacts.

Real cases in relation with future projects, should ideally be simulated using such detailed approach, but numerical simulation with true data will surely not be an easy way. However, it is only on the basis of accurate predictions (i.e., about long term efficiency and possible expected impacts) that the financial risk could be assessed for decisions.

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Session Classification : Parallel
Track Classification: Topic 10 - Urban groundwater
Induced land subsidence due to groundwater withdrawal compared to rising sea-levels in sinking cities

Tuesday, 24 September 2019 12:00 (15)

Much attention is paid to sea level rise but the problem of land subsidence, induced by man-changed groundwater conditions, can be (until now) by far more significant locally (Showstack, 2014). The ‘sinking’ regions correspond most often to urban coastal densely populated areas located in regions where compressible loose sediments are found. As they are usually under-consolidated and compressible, geological settings made of recent coastal and especially estuarine, deltaic and lacustrine sediments are particularly concerned. Venice, Mexico, Bangkok, Shanghai, Changzhou, Jakarta, Manila, New Orleans, Houston, Tokyo, Ho Chi Minh City, Hanoi, ... are only a few examples among the numerous ‘sinking cities’ (Gambolati & Teatini, 2015), with cumulative land subsidence ranging from 0.5 to 12 m.

Recent unconsolidated or semi-consolidated deposits form often a succession of layers that can be considered, from a hydrogeological point of view, as semi-confined or confined aquifer systems (Poland, 1984). In confined aquifers but also in unconfined aquifers, the lowering of the piezometric head due to pumping or drainage induces additional effective stresses directly in the concerned aquifer and then, with a delay depending on their characteristics, in the compressible confining layers or in the compressible lenses of loam, clay, and peat included in the aquifer.

Coupling the transient groundwater flow equation with geomechanical aspects, allows understanding the considered transient processes induced by the artificial lowering of the water pressure in the porous medium. For accurate calculations, used for understanding the observed subsidence and predicting the future subsidence, it is important to take into account the strongly non-linear effects as the variation of the specific storage coefficient and of the permeability during the consolidation process (Dassargues, 1995, 1997, 1998, 2018).

Recently this issue was back to the forefront of the scientific actuality as land subsidence plays an important role linked to global change and groundwater management challenges (Gorelick & Zheng, 2015). During the last century, if we take the city of Bangkok as an example, a 20 cm sea-level rise is to be compared to more than 210 cm of land subsidence. Indeed, a critical situation is created knowing that, on one hand, groundwater pumping is far to be stopped and, on the other hand, global warming will cause an additional sea-level rise ranging from 0.5 m to 0.9 m (according to the latest IPCC reports and for the worst scenarios), making the situation even more difficult. Other typical and emblematic examples involving regional as very local land subsidence are given.
GIS-based distributed water balance model for groundwater recharge in an environmental protection area, Brazil

Thursday, 26 September 2019 16:00 (60)

Due to the flexibility and reliability of GIS-based index models, they have become an alternative for mapping and interpreting aquifer recharge systems. The Serra de Santa Helena Environmental Protection Area, next to the urban area of Sete Lagoas (MG), Brazil, had a rapid economic growth resulting in a subsequent expansion of the nearby urban area. Because of this, it was selected as the study area in order to develop an index method for distributed recharge by integrating water balance parameters (surface runoff, actual evapotranspiration, percolation) estimated by Thornthwaite and Mather’s method and adapting the Fenn et al. (1975) method, with maps of soil texture, land cover, and terrain slope, for a sustainable use of the groundwater resources. In the first stage, a surface runoff map was built overlaying maps of soil, land cover, and terrain slope according to their permeability capacities. For the second stage, a water balance was made to estimate values for different water percolations. In the third and last stage, values of water percolation (calculated in stage 2) to develop the final groundwater recharge zone map were established. Large variability in soil type, land use, and slope in this region resulted in spatially complex relationships between recharge areas. Due to these conditions, the study area was divided into four zones, according to the amount of recharge: high (> 100 mm/yr), moderate (50–100 mm/yr), low (25–50 mm/yr), and incipient (< 25 mm/yr). The technique proved to be a viable method to estimate the spatial variability of recharge, especially in areas with little to no in situ data. The success of the tool indicates it can be used for a variety of groundwater resource management applications.

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Session Classification : Poster with refreshments

Track Classification : Topic 9 - Groundwater and socio-economic development in Latin-America
Adapting the EPIK method to Brazilian Hydro(geo)logical context of the São Miguel watershed to assess karstic aquifer vulnerability to contamination

Thursday, 26 September 2019 16:00 (60)

Karst aquifers are, besides important strategic reservoirs of good quality water, heterogeneous and anisotropic, where highly permeable karst networks result in insufficient time for contaminant degradations, and hence the quasi-immediate contamination of the aquifer. The EPIK method is a low-cost technique and was developed to map karst regions based on four main feature indexes: 1) epikarst; 2) protective cover; 3) infiltration conditions; and 4) karst network development. However, the method was developed according to European hydrogeologic and temperate climatic contexts, where its application without adaptations in regions in different contexts may result in possible misunderstandings, such as overlook, underestimate or overestimate significances of some parameters (e.g. soil covers, rainfall regimes, morphological domains). The Brazilian São Miguel watershed, a tropical karst region where the city of Pains is located (southwestern Minas Gerais), is characterized by high levels of thermotolerant coliforms, phosphorus, nitrate, and cadmium in surface water and groundwater. These contaminants come from agriculture, livestock, and urban areas. Due to these issues and to provide a tool of water resource management and land use planning, the EPIK method was adapted to the hydrogeologic reality of the São Miguel watershed, considering both local vegetation and the current Brazilian speleological heritage protection legislation. The study was developed over the course of three stages: bibliographic review (1:100,000 geologic and geomorphologic map), field survey (in June 2017, consisted on geological prospection, soil thickness measurements, and mapping of karst features), data analysis, and geoprocessing. Results revealed that 52% of the area has moderate vulnerability and 7% high vulnerability, this latter one concentrated in areas close to mining activities and urban areas. The 250 m buffer around caves or superficial karstic features incorporated into the method based on the Brazilian speleological heritage protection legislation (CONAMA nº 347/2004), even not being an indicator of karst natural vulnerability, can consequently add to the final map perimeters of protection in areas more sensitive to contamination, being considered an automatic management tool. The study provided a reliable map and adapted technique which can be used in other Brazilian karst regions and other tropical karst regions.

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Session Classification : Poster with refreshments

Track Classification : Topic 7 - Karst Hydrogeology
ISOTOPES AND NOBLE GASES INVESTIGATION OF SOUSS-MASSA AQUIFER, MOROCCO.

Monday, 23 September 2019 12:15 (15)

The Souss-Massa Basin, an important agriculture area of Morocco, is located in a semi-arid area and its main water resource is the groundwater. Over the last decades, population growth, agriculture development and recurrent droughts have been increasing the pressure on the aquifers of the region.

In this context of climate variabilities (changes) and increasing demand for water, it is crucial to identify the origin, groundwater flow dynamics and mean residence times for sustainable management of water resources. In this study, groundwater residence time and recharge conditions of the Souss-Massa aquifer system were investigated using environmental isotopes (δ18O, δ2H, δ13C, 14C, 3H) and noble gases. The results shows that the aquifer is mainly recharged by waters derived from the High Atlas Mountains, where the precipitation rate is higher than in the study area. The spatial variations of stable and radioactive isotope concentrations indicate that active mixing of recently recharged and old groundwater within the aquifer system. The recent recharge is observed mainly along the Souss River and in the irrigated areas.

According to radiocarbon activity, two groups of waters are defined: recent (14C activity >60 pmC) and old (<30 pmC). Groundwater plotting between these two types can be used as evidence of water mixing processes. Based on the mean regional temperature of 20°C, we can also distinguish two groups of samples: low and relative higher noble gas recharge temperature. Recent and sub-recent waters show recharge temperatures ranging from 13.5 to 24.5°C, with an average around 18.3°C, which is consistent with the monthly inter-annual average temperature of 18.75°C ± 1°C recorded at the meteorological stations Agadir and Taroudant. However, the estimated noble gas temperatures in areas located near to the recharge zones, are still about the annual average local temperatures reflecting relative low contributions of water from the high elevated areas of the Atlas Mountains. The NGT of all samples collected from shallow wells are generally midrange of their annual average temperature at each location. The Turonian water has a recharge temperature of about 18 °C with a radiocarbon age higher than 19000 years BP.

The study clearly showed that long term recharge conditions and groundwater flow processes, are influenced by natural climatic variability and anthropogenic impacts.

This study indicates the extent of groundwater renewability and allows establishing a scientifically-based water management model for sustainable exploitation of water resources in the Souss-Massa Basin.

Keywords: Stable isotopes, Radiocarbon, Noble gases, Paleotemperature, Groundwater age.

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Session Classification: Parallel
**Track Classification**: Topic 5 - Tools, methods and models to study groundwater
The importance of biological processes in quantifying the connection between wetlands and groundwater

The connection between a wetland and surrounding groundwater depends on more than the commonly measured physical parameters of hydraulic conductivity and hydraulic gradient. Biological processes also can induce substantial exchange across the sediment-water interface in wetland settings. Influences are broad and range from near-shore transpiration of groundwater, to filtering animals on and in the sediment bed that measurably influence seepage rates, to decomposers that generate gas that can both accumulate, reducing sediment permeability, or be constantly or episodically released to surface water and interpreted as seepage. High-temporal-resolution seepage measurements can indicate the magnitude, frequency, and duration of these biologically driven seepage rates. For example, relatively fast upward seepage in the wetland margin of a small lake varied diurnally by more than 30 percent as plants growing on an adjacent peat surface intercepted groundwater before it could discharge to the lake. Vertical hydraulic gradient, meanwhile, was stable. Shrimp on or near a sediment bed in an estuarine setting in the northwestern United States caused seepage to flow in the opposite direction of that indicated by adjacent seepage meters where shrimp were not present. At a different estuary in New York City, another species of shrimp created highly variable seepage that averaged 20 times faster than other nearby measurements. A few hundred meters away, decomposers created a measurable influence on seepage. More than three liters of gas was released during several hours that spanned low tide. The inferred seepage caused by this ebullition was four times faster than the average seepage measured at that location. These and other data indicate that we may underestimate the connection between groundwater and surface water when we determine flow based on hydraulic gradients and do not consider biological processes. Although biological processes likely exert a very small influence during most seepage measurements, water and associated chemical fluxes caused by biological processes can be important to consider and can be much larger than gradient-based flows in some wetland settings.

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Session Classification : Plenary
Track Classification : Topic 6 - Groundwater, wetlands and natural heritage
Experimental research on determination of hydrogeological parameters of filled fractures by slug test

Tuesday, 24 September 2019 16:00 (60)

In order to improve the efficiency and accuracy of determining the hydrogeological parameters of filled fractures, the slug test models without considering or with considering the inertia effect were deduced under the condition of finite distance radial constant head boundary. The relationship between the critical distance affected by radial constant head boundary and dimensionless storage coefficient of filled fractures satisfies the power function formula through type curve analysis. The water head response characteristics of filled fracture to slug test were revealed by analyzing the type curves in different radial positions, which provides a theoretical basis for calculating the hydrogeological parameters of filled fractures using the piezometric tube data or observation well data. In a slug test simulation platform with radial constant head boundary, water injection, pumping and pneumatic slug tests were carried out. The matching results of dimensionless water level in piezometric tubes show that the matching degree of pneumatic slug test is the highest, followed by water pumping slug test, and the worst is water injection slug test. The higher the matching degree with the type curves is, the higher the quality of the data is, and the more reliable the hydrogeological parameters calculated by this method are. The actual calculated values of storage coefficient and transmissibility coefficient also verify this index. The hydrogeological parameters determined by three kinds of slug tests show that the test platform has obvious heterogeneity. The storage coefficient and transmissibility coefficient near the main test well are larger, while the storage coefficient and transmissibility coefficient far away from the main test well are smaller.

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Session Classification : Poster with refreshments

Track Classification : Topic 5 - Tools, methods and models to study groundwater
The impacts of climate change are significant on both surface and groundwater resources. However, little attention has been given to the effect of climate change on groundwater resources. Therefore, the present study is concerned with the effect of climate change on groundwater recharge and base flow in Muda River Basin, Malaysia. The model simulations were based on 55 years of historical rainfall and runoff data (1960–2015) while climate change scenarios were run for 50 years from 2016–2050 using different downscaled Global Climate Model projections. The future climate variables were obtained from five GCMs projection were downscaled. These GCMs include i) CanESM2 from Canadian Centre for Climate Modelling and Analysis, ii) GFDL-CM3 from Geophysical Fluid Dynamic Laboratory NOAA, iii) HadGEM2 from UK Met Office, iv) IPSL-CM5 from Institut Pierre-Simon Laplace and v) MIROC5 from Japan Agency for Marine-Earth Science and Technology Frontier Research Centre for Global Change. For each GCM downscaled projection, results for two representative concentration pathways (RCPs) have been produced, namely: RCP 4.5 and RCP 8.5. These pathways describe possible future climates depending on how much greenhouse gases are emitted in the years to come. The results indicated the average annual runoff resulting from each GCM, three future possible climate scenarios were determined as Dry (CanESM RCP4.5), Intermediate (HadGEM2 RCP8.5) and Dry (MIROC5 RCP4.5) The results of this study would help policymakers, scientists, government officials and local stakeholders in planning and management of the surface and groundwater resources in the Malaysia regions.

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**Session Classification :** Parallel

**Track Classification :** Topic 2 - Groundwater and climate change
In Kenya, as in much of Africa, there is significant growth in water-reliant industry. In 2016-17 much of East Africa was affected by a severe drought. During such events, groundwater resources can act as a buffered resource, but may themselves be stressed by reduced recharge and increased abstraction, posing significant challenges to water resource management. Despite the importance of groundwater use in the continent, there is a lack of knowledge of the groundwater hydrodynamics of many African aquifers. The aim of this study is to characterise the groundwater system in Kwale County in south-eastern Kenya, examining the possible influence of increased abstraction by new industry and agriculture and determine the effects of the 2016-17 La Niña drought. This area has been selected as an aquifer representative of much of coastal East Africa, where new water-reliant activities (mining and irrigated sugar) were established in 2012-2013; these coexist with the long-standing tourism industry and local communities.

Diverse hydrochemical, isotopic, geophysics and groundwater level measurements were carried out to study the groundwater hydrodynamics and characterise the aquifer system before and during the drought period. The recharge in the study area was estimated using the soil mass balance. Due to the difficulties in obtaining good abstraction data, different information sources were used to determine the groundwater abstraction of the different water-reliant industries. These included direct information from the companies and using Google Earth, Trip Advisor and interviews to define hotel abstractions.

The results show that the current level of groundwater abstraction does not significantly affect aquifer water levels. However, during la Niña there was a 69% reduction in recharge compared with an ‘average’ climate year. Furthermore, there was a concurrent increase in seawater intrusion even during the wet season. The main impact occurred to community handpumps, prone to drying up during drought periods, as they exploit a shallow aquifer that is less resilient to drought. On the contrary, groundwater abstraction by irrigated agriculture and mining is from the deep aquifer, which is more resilient to the drought periods common in the area.

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Session Classification: Poster with refreshments

Track Classification: Topic 3.1 - Groundwater and water security in developing countries
Hydrogeological context of Ollachea road tunnel  
(Puno District; Peru)  

Tuesday, 24 September 2019 16:00 (60)

The Southern Interoceanic Highway corridor is a toll road that links Peru with Brazil, crossing the Andes range, in the Central Volcanic Zone. Between km 231 + 700 and km 232 + 820, the road runs along the river Ollachea, through a narrow and deep canyon, with very steep slopes (45 ° to 60 °). The road is often cut by landslides and rocks avalanches, which has led to project a tunnel to avoid this conflicting section of the canyon.

The projected tunnel will pass through rocks formation which are very affected by the subduction of the Nazca Plate under the South American Plate. This is a very active geodynamic setting, affected by thrusting faults, volcanism, erosion, ... Given the presence of hyperthermal waters accompanied with high pressure gases, the hydrogeological characterization has demanded the implementation of innovative research techniques.

The tunnel will cross geological formations that correspond to the Upper Ordovician (sandstone quartzites with interbedded shales), Silurian (siltstones and sandstones / slates and shales), Cretaceous - Miocene (andesitic lavas) and Quaternary (colluvial debris). The formations have developed a tectonized complex, affected by overthrust faults and very deep sub-vertical faults. The hydrogeological research was supported by data obtained mainly through sub-horizontal holes. The drills are performed from the existing road, crossing faults, fractures and brecha rocks, producing continuous upwelling of hot water.

Those research holes, together with hydrochemicals, thermometric and hydrodynamics studies, have allowed to locate very penetrative deep faults, with thermal up-flow (temperature above 90 ° C), spanning the thrust surfaces (reverse faults of low-angle). The fissured rocks associated with faults, appears filled by crystallization of calcite along the strip where gases are released. Orthogonal faults to the later have also been found. Thermal waters mixed with storm water infiltration, discharge to the Ollachea River through these orthogonal faults.

The hydrogeological environment (lithology, faults, fractures, RQD, filling of fractures, weathering, ...) has been characterized by sub-horizontal research holes. Hydrodynamics parameters (mainly permeability) have been determined through depressurization test (Lugeon) in sub-horizontal holes, very complex in its execution, because of the pressure of water and the high temperatures.

The rock compound shows, in general, low primary permeability, which is overlapped by a very heterogeneous secondary permeability caused by fracturing. Finally, permeability is reduced by calcite deposits, originated by the depressurization and degasification of hyperthermal waters of deep origin.

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Session Classification : Poster with refreshments
Track Classification : Topic 5 - Tools, methods and models to study groundwater
Climate change and future developments can influence the availability of groundwater resources for water supply. To mitigate their effects on aquifers systems and the dependent human communities and industrial activities in Africa, it is relevant to consider them in long-term water management plans. In order to advance this understanding, this study described here evaluates the effect of climate change and anticipated increased groundwater demand from a coastal aquifer located in southern Kenya (Kwale County). A previously calibrated numerical groundwater flow model has been used as an assessment tool to study how future climate (precipitation and temperature variation) and groundwater abstraction changes will affect the aquifer system. The groundwater flow model was constructed using Modflow-2005 to simulate the period 2010 to 2017, and 8 future model scenarios developed that cover the hypothetical years from 2018 to 2023. Future rainfall scenarios have been constructed based on long historical data series (from 1959 to 2017) and the Standard Precipitation Index. Future abstraction has been based on current abstraction and future estimations made by to Water Resources Authority water allocations. The main results show that in a succession of prolonged dry seasons the groundwater level decline in the shallow aquifer can reach five meters, with important implications for local community water supplies. Effective recharge depends on precipitation distribution throughout the year, with important implications for both dry periods and also for “average rainfall years”. The most significant groundwater decline in drought periods is observed in the vicinity of the pumping deep aquifers wellfields, where the effects of drought and significant abstraction are multiplied. However, the effect of increased abstraction on the shallow aquifer system is limited. Despite groundwater level decline observed during prolonged dry periods, a dry period followed by a humid period leads to the relatively swift recovery of the groundwater system.

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Session Classification : Parallel
**Track Classification**: Topic 2 - Groundwater and climate change
Hyperthermalism in the Ollachea Tunnel (Puno, Peru)

Friday, 27 September 2019 11:30 (15)

The Ollachea tunnel is to be excavated in Section 4 of the Interoceanic Road Peru – Brazil, at 3,000 m altitude. The environment shows the presence of numerous hyperthermal springs and a thermal spa in exploitation, which requires to study the thermal conditions that will affect the excavation works.

A first set of information has been provided by 16 thermal springs, with temperatures between 21 ºC and 78 ºC. More detailed data has been obtained thanks to three research holes drilled from the left bank of the Ollachea River Canyon, 13 sub-horizontal holes (0 º to -5 º) and 3 descending holes (-13 º to 75 º); six of them with lengths between 150 m and 226 m. These holes have provided accurate information about the geological formations that will be present along the tunnel. The very abrupt morphology of the canyon, along which the road runs, has made it impossible to drill vertical holes on the path of the tunnel or its immediate surroundings.

Groundwater in this context is classified as mesothermal (30 ºC to 50 ºC), hyperthermal of low enthalpy (up to 70 ºC), and medium enthalpy (from 70 ºC up to more than 90 ºC).

The isotherms maps at the tunnel level (isolines of 30 ºC to 90 ºC) define the presence of major subvertical faults, and evidence that the contributions of thermal water are concentrated in the quartzites of the Upper Ordovician and in the andesites of the Cretaceous.

All this information has enabled: the location of subvertical deep faults that act as thermal flowways; the establishment of the planimetry of the water isotherms in the path of the tunnel and along its axis; the verification of thermal reservoir temperatures (at least between 138 ºC and 190 ºC); and the design of the geothermal conceptual model, consistent with the extensive collected information.

In summary, all this data has been fundamental to define the best location and path for the tunnel and to establish its construction project, taking into account the high temperatures of water and rock types to be crossed.

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Session Classification : Parallel

Track Classification :  Topic 9 - Groundwater and socio-economic development in Latin-America
Use of electrical conductivity for stratigraphic correlation and estimation of permeability in variable density aquifers

Tuesday, 24 September 2019 16:00 (60)

Multiple geophysical techniques are used to recognize unexposed geological materials and their spatial correlation. However, the perforation of one or several boreholes most of the times is needed. In these cases, the geological formations can be identified from the drill cutting and also through geophysical well loggings using parameters such as Gamma-Ray or Resistivity. In variable density aquifers, such as coastal aquifers, the water salinity is stratified from freshwater on the top to saltwater at the bottom. An electrical conductivity log run in a water well permits determining the exact depth and thickness of these fresh, salt and interface water bodies, but the geological characteristic of the traversed materials can’t be characterized. In cases where there are several sub-aquifers, this picture is more complicated and this technique would not be applicable.

Nevertheless, pumping of the saline water with large discharge nearby the boreholes cause the distribution of salinity to change dramatically, exhibited in a salinity decrease landward. Once the pumping stops, the salinity distribution tends to adopt the previous configuration. The speed of this recovery depends on the permeability of the different materials in the aquifer. Thus, in a multilayer aquifer, the electrical conductivity logs obtained during the aquifer recovery will show larger salinity peaks in those more permeable rock formations and lower values in lithology associated with a low permeability. The resolution of these fluctuations can be metric, and it is possible to correlate them with logs measured in others boreholes affected by the pumping.

This technique has been used in Andarax coastal aquifer (SE Spain) allowing to correlate materials several hundred meters away. These correlations have been compared with the stratigraphic logs from the drill cuttings and with others geophysical logs, being more accurate the first of the indicated tools. Moreover, using this technique, it is possible to get qualitative information about the permeability of different materials.

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Session Classification : Poster with refreshments

Track Classification : Topic 5 - Tools, methods and models to study groundwater
Evaluation of groundwater environment changes due to urbanization in the Tokyo metropolitan area, Japan: Application of subsurface temperature observation integrated of long-term monitoring and repeated measurement of temperature-depth profiles

Tuesday, 24 September 2019 11:45 (15)

Urbanization and human activities in the Tokyo metropolitan area have induced various changes of groundwater environment, such as groundwater flow regime and subsurface temperature distribution. Additionally, subsurface temperatures have been affected by surface warming caused by not only urbanization but also global warming. Thus, it is essentially required to clarify the mechanism and process of changes of subsurface thermal distribution and to evaluate the present situation of that in this area for sustainable management of groundwater environment.

We have conducted repeated measurements of temperature-depth profiles at observation wells which are for groundwater levels and land subsidence to grasp the three-dimensional distribution of the subsurface temperature and its secular change since 2000s. We also have carried out subsurface temperature monitoring using high resolution and accuracy temperature loggers (resolution: 0.001K) for two or more years to find the subsurface temperature change in detail. In addition, the groundwater flow regime has been evaluated based on distribution of hydraulic heads obtained by the observation wells.

Secular subsurface warming was found at shallow depths in the whole study area, that is, not only in urban area but also suburban areas. Warming trends in the urban area which were estimated by repeated measurements of temperature-depth profiles were higher than that in the suburban areas. The warming trends obtained at each well were decreased in accordance with depth. These tendencies suggest that the subsurface warming has been caused by the effects of both urbanization and global warming. As for the effect of urbanization, subsurface warming has been induced by the heat from not only the ground surface but also the subsurface constructions such as basements and subway.

Subsurface temperature beneath the urban center was particularly high even in the deep part. On the other hand, in the suburban areas, the subsurface warming in groundwater development areas were recognized at the relatively deep part, even though the effects of surface warming were relatively small. The results of the monitoring showed continuous warming tendency beneath both the urban center and the suburbs. However, the warming at 40m deep at the urban center showed fluctuations in the interval of few months. This result was considered to be induced by heat supply from the subsurface constructions. Differences of the tendencies between the urban center and the suburbs suggest the possibility to separate the effects of the urbanization and the climate change due to global warming in the Tokyo metropolitan area.

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Session Classification : Parallel

Track Classification : Topic 10 - Urban groundwater
Using Geochemical Data and Aquifer Simulation to Characterize a Carbonate Aquifer (Balanegra, SE Spain)

Thursday, 26 September 2019 16:00 (60)

The Balanegra aquifer, located in Almeria (SE Spain), has a complex geometry as a consequence of the lithological diversity and structure of the area. The main economic activities in this area – a highly profitable irrigated agriculture and tourism – are supported by groundwater, hence the interest in understanding this aquifer system.

In order to identify the origin of the main processes that affect the composition of groundwater in a karstic aquifer, a hydrogeochemical study was carried out from numerous observation wells. Analysis of major ions enabled the principal geochemical processes occurring in the aquifer to be established, and the samples were classified into distinctive solute groups according to this criterion. The carbonate aquifer does not appear to behave homogeneously from a hydrochemical point of view. Thus, three zones were distinguished, being the groundwater temperature one of the parameters that conditions this classification.

The combination of the hydrogeochemical analyses with geochemical simulations has been effective identifying the different physicochemical processes in the aquifer, thus improving understanding of hydrogeochemistry in complex aquifers. Processes of precipitation / dissolution of minerals associated with the circulation of the samples analyzed through carbonate rocks, marine intrusion and anthropogenic contamination processes were identified using the characteristic ionic relationships and ionic delta.

To determine which of the identified processes are taking place in the aquifer, the following inverse simulations have been carried out:

1. Conservative mix between seawater and freshwater.
2. Conservative mix between seawater and freshwater with water / rock interaction.
3. Water / rock interaction.

The main mineralogy of aquifer lithology, calcite, dolomite, gypsum and halite, was used. The simulations undertaken corroborate the processes identified, reproducing the hydrogeochemical compositions revealed from laboratory analysis. These processes do not act individually, but at the same time and with different intensities in the three zones identified, being more evident in areas with a higher salinity. Besides, hydraulic connectivity between two zones has been identified.

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Session Classification : Poster with refreshments

Track Classification : Topic 7 - Karst Hydrogeology
Analysis of hydrographs from a karst aquifer in a former mining area, Hungary

Monday, 23 September 2019 16:00 (60)

The Transdanubian Range is a complex, thick karst aquifer, which can be characterized by hydraulic interrelationships. Because of mining, a large amount of groundwater was extracted from this area in the second part of the 20th century for a preventive purpose. At the end of the 90’s, the mining was stopped, and the rising of karst water has begun, which led to serious economic and technical-engineering problems as well. The examination of hydrographs of observation wells, showing the recovery process, helps to understand the hydraulic behaviour of the karst aquifer and to prepare for problems related to the phenomenon.

The aim was to understand this special hydrogeological situation by applying stochastic approaches. 127 long-term time series could be analysed from the area of the depression having affected by water recovery. The time series (from 1995 to 2015) located in the study area have been grouped into three clusters with hierarchical cluster analysis based on their pattern. The individual groups were separated prior to their spatial positions related to the depression centre. The water levels of the first group showed significant (30-40 meters) and continuous rising. The water levels in these wells are characterized by less fluctuation and the effect of the recovery is crucial. These wells are located in the NE part of the study area. In the wells of the second group the water levels increased tens of meters as well, moreover, a definite fluctuation pattern has also occurred. These wells are located in the area represented by high water level of topographic heights. The wells of the third group are situated in the SW part of the study area where the rising of the water level is also typically tens of meters (some places more than 70 meters) but without a fluctuation pattern. As a next step, the forecast of the water levels in each individual well took place with the estimation of a well-fitting trend and their extrapolation until January 2030. Thus, the so-called growth curves, which has an upper limit, have been fitted to the time series describing appropriately the recovery process. A significant part (82.68%) of the studied hydrographs showed an excellent fitting (where R^2 > 0.9). In most cases, out of the 10 examined functions, the process can be modelled most accurately by the so called “Richards” and “63%” functions. Important result of the research is, that using the growth curve models can expand the number of methods which may be used in forecasting groundwater levels.

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Session Classification : Poster with refreshments

Track Classification : Topic 5.3 - Advanced modelling tools for subsurface hydrology: from
the vadose zone to deep environments
Hydrogeological database focused for sustainable management of groundwater in San José de Chiquitos. Santa Cruz, Bolivia

Friday, 27 September 2019 11:15 (15)

Groundwater flow models are often used for scenario calculations, decision-making and sustainable groundwater management. Their reliability and validity depend to a large extent on the availability of a large volume of data, ideally integrated in a spatial database.

In Bolivia, there is a lack of hydrogeological data, groundwater monitoring and databases allowing the construction of numerical groundwater flow and transport models. Given this situation, it is essential to start generating and organizing this information in such a way to allow developing of groundwater models.

With this goal, a first hydrogeological data base was built in the region of San José de Chiquitos, Santa Cruz, Bolivia, in a geographic information system (GIS) that integrates topographic, meteorological, hydrogeological and hydrogeochemical information of the study area.

Its first strength is that it is designed in such a way that it can be linked to MODFLOW (groundwater flow modeling software) and perform numerical simulations of subsurface flow. The second quality is that its implementation has been carried out with the participation and involvement of local actors who can initially visualize relevant information and eventually run simulations which ensure its sustainability; different actors and stakeholders have been actively involved through accompaniment and training. These activities are in favor of sustainability and will ensure continuity in the operation of the monitoring network and the introduction of aquifer information and monitoring that nurtures the database.

This project constitutes the first phase of the doctoral thesis of “Sustainable management of the aquifer of San José de Chiquitos, Santa Cruz, Bolivia”, which is developed within the framework of the project “Contribution to integrated water management in Bolivia”, carried out by the Bolivian Catholic University, in coordination with the Vrije Universiteit Brussel, Belgium.

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Session Classification : Parallel

Track Classification : Topic 9 - Groundwater and socio-economic development in Latin-America
New insights into karst genesis processes in unsaturated zone thanks to process-like modelling

Thursday, 26 September 2019 16:00 (60)

Predicting the position and the geometry of karst conduits remains a challenge for both geologists, hydrogeologists and geophysicists. Karst genesis requires a successful mixture of suitable geological properties of rock, geomorphological structures and hydraulics. Generally, the winning combination varies according to the case and the location in the aquifer, even if one single prevalent type of feature usually drives the development of karst conduits. For instance, while faults and fractures control the genesis of vertical conduits in the vadose zone, bedrock planes assist the development of sub-horizontal conduits near the water table of the saturated zone. Despite the simplistic idea behind these concepts, they highlight the difficulty to quantify the role of each feature and their interaction with others in karst genesis. Actual systems show incredibly complex organisation of karst networks and numerous caves topographies let us wondering about their genesis. Therefore, their prediction would require tools able to simulate this genesis.

Thanks to numerous cavers, in the Fontaine de Vaucluse karst system (south-eastern France), topology of several caves has been described and digitized in 3D. The database includes almost 27km of conduits. The usual first-order classification is respected with vertical conduits developed along faults, while sub-horizontal conduits are linked with ancient water tables and dipping conduits are parallel to rock strata. However, it remains very difficult to clarify why one given type of conduit developed locally, nor why one type of conduits becomes one other few meters away along the flowpath.

gOdiagTM is an in-house modelling tool developed in Total SA. It uses a cellular automaton to mimics genesis of karst conduits in geological models. This is a powerful solution, particularly because of its numerical efficiency and its ability to encompass main features involved in karst genesis. The displacement of particles within matrix (grid cells) and fractures (selected edges of the grid cells) represents the water flows in the gas on network. It is controlled by the medium permeability and a simplified pressure gradient. When they displace, the particles can dissolve the rock matrix and create conduits along fractures or beddings, which increases permeability, with an intensity dependent on the aggressiveness of the water and the vulnerability of the rock.

In this study, gOdiagTM was used to benchmark different scenarios of karst genesis consistent with observations in the Fontaine de Vaucluse karst system. Notably, simulation results allow identifying favourable conditions for conduits inception along specific bedding planes in the unsaturated zone. More generally, this study highlights the relevance of process-like modelling to enhance concepts inferred from observations in the field.

The authors thank TOTAL for funding this R&D project and giving permission to publish this paper.
Track Classification: Topic 5.1 - Dynamic Analogues
Quantification of large-scale groundwater resources in karst aquifers within the Mediterranean region under the light of long-term shifts in climate

Thursday, 26 September 2019 12:00 (15)

The Mediterranean region is one of the “hotspots” of predicted shifts in climate and will be affected by increasing water scarcity in the near future. Karstified aquifers are vulnerable to changes in the hydrological cycle. We here present a numerical model of the Western Mountain Aquifer (WMA), a transboundary aquifer between Israel and the Palestinian Territories, with a size of 9,000 km². Due to a high politically-driven data scarcity a stochastic modelling concept using the MODFLOW is developed that considers the aquifer development and changes in climate of the last 5 Mio. Years BP and also the future.

For the design of the karst network it was necessary to reconstruct the karst development. Carbonate rocks of the WMA were folded during the Oligocene into several NNE-SSW-trending anticlines and subsequent erosion resulted in today’s recharge areas. Major changes in sea-level, especially during the Messinian Salinity Crisis, drove the formation of deep, multi-layer karst conduit systems (Laskow et al. 2011). Vertical distribution of conduits was controlled by i) sea-level changes and ii) the depths of new canyons draining the entire catchment. Especially within the coastal plain highly permeable karst was developed, explaining the low South-North trending hydraulic gradient. Karst conduits also cross the aquitard connecting Upper and Lower Aquifer.

Parameterization and location of the karst features are defined with a stochastic prediction of the karst networks distribution using a new pseudo-genetic algorithm (Stochastic Karst Simulator SKS, Borghi, 2012) and then transferred into probability density functions (PDF). Based on the PDF-information, a karst conduit network is generated that connects the recharge areas with discharge points. Locations of assumed individual karst conduits and the geometry of the karstified horizons are calibrated by geophysical borehole data.

The different degrees of karstification are converted into hydraulic parameter fields. This process results in a catalogue of groundwater models. The stochastic concept is suitable to parameterize large-scale groundwater systems with only a limited number of data available and depends less on the availability of high-quality observation time series.

Climate projections show that during winter temperatures will rise in the recharge area by 2℃ increasing evaporation rates. However, total precipitation will decrease by 20%. Climate modelling indicates that a larger proportion of rainfall will occur during extreme events with an increase of the total amount of 10% affecting mostly the Northern recharge area. We therefore expect, that the impact of regional shifts in climate on recharge rates and groundwater resources will be impressive. Therefore, based on the calibrated groundwater model the response of the groundwater system to predicted changes in climate is analyzed. For this purpose, climate data from a high-resolution (~2 km grid) regional climate model between 2041-2070 are currently investigated and coupled with the groundwater model.

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Quantification of large-scale groundwater flow in karst aquifers

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**Session Classification**: Parallel

**Track Classification**: Topic 7 - Karst Hydrogeology
Numerical investigation of the combined effect of different driving forces in the Buda Thermal Karst, Hungary

Based on field observations and previous numerical simulations, combined effect of external forces (e.g. water table elevation) and buoyancy forces can cause a complex groundwater flow pattern characterized by mixed thermal convection, not only in siliciclastic sedimentary basins, but also in adjoining karstified deep carbonates.

The interaction of different driving forces was examined along a two-dimensional west-east geological section across Buda Hills (Rózsadomb) to Gödöllő Hills. On the course of this study three simulation scenarios were systematically examined in the last evolutionary stage of Buda Thermal Karst: (a) a purely topography-driven steady-state groundwater flow, (b) a topography-driven steady-state flow system with forced thermal convection, and (c) a time-dependent flow system with mixed thermal convection. The numerical model was verified using the results of basin-scale hydraulic evaluation (observed pressure elevation profiles, tomographic potentiometric maps) of Mádl-Szőnyi (2019) complemented by estimated recharge rates, and calculated heat fluxes. The effect of different flow and thermal boundary conditions was systematically tested during the simulations.

Effect of thermal convection was studied in order to examine its influence on the temperature distribution and on the groundwater flow pattern. It was established that existence of thermal convection increases the heat flux compared to the conductive model in agreement with values of the Nusselt number from 1.5 to 5 in model (b) and (c), respectively. The pure advective heat transfer due to forced convection causes a large hot upwelling with a surface temperature of 60 – 80 °C beneath the regional discharge area in agreement with the temperature depth profiles and appearances of thermal springs. However, the effect of time-dependent free thermal convection also facilitates small hot upwellings in the unconfined karstified carbonate system which might elucidate the unexplained heat anomalies in temperature maps and profiles. In addition, the effect of free thermal convection increases the value of the monitoring parameters in the models (e.g. Darcy flux, temperature and hydraulic head).

These simulations draw attention to the importance of different driving forces of groundwater flow, especially at the margin of unconfined and confined carbonate sequences, such as in Buda Thermal Karst. Thorough comparison of the numerical results and the observation data could improve understanding the interaction caused by mixed thermal convection.

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Session Classification :  Parallel

Track Classification :  Topic 5.4 - Innovative approaches for understanding groundwater flow systems
An Example of Inverse Delineation of Basin Boundaries Based on Water Budgeting in Highly Karstified Terrains

Thursday, 26 September 2019 11:30 (15)

Globally, karst aquifers are one of the most significant sources of drinking water. Although characterized by variable regimes, karst groundwater has excellent natural quality. The main prerequisite for successful utilization and management of karst groundwater is the proper evaluation and characterization of a karst hydrogeological system. It is very important to define the hydrogeological parameters of a system, its boundaries, and the amount of groundwater that could be sustainably used. Delineation of the catchment area is one of the most complicated tasks in karst aquifer characterization, but it is necessary when it comes to the definition of sanitary protection zones. Due to high seasonal fluctuation of groundwater tables, it is very common in a highly karstified area to discover reorientation of the groundwater flow and the changes of the basin’s boundaries. The catchment area of a karst aquifer usually consists of an autogenic and an allogenic part of the recharge area, where the former is consistently very difficult to identify.

This article discusses a case of inverse definition of karst spring catchment boundaries based on water budget and systematic measurements of spring discharge and precipitation. The studied area covers the karst spring Vučkovo vrelo, located in the vicinity of the city of Sjenica in SW Serbia. The catchment area at the karstic Pešter Plateau consists of Triassic limestone and dolomites (autogenic recharge), which are in some areas partly covered by Jurassic ophiolites and Miocene sediments. The karst spring discharge rate has been monitored since 2016, while precipitation data has been collected since 1950s. On average, at this spring, the karst aquifer annually drains a total water amount of 7.9 x 106 m3, while the sum of the annual rainfall in an average hydrological year for the concerned period is 850 l/m2. Some water budget components are approximated by necessity, or values have been used by analogy. Such is the case with effective infiltration (Ief), which is estimated to be 55% of the rainfall on average. This value resulted from calculated evapotranspiration of 35%, based on Turc’s equation, with an estimated runoff of 10%. At the Vučkovo vrelo spring, this approach resulted in the catchment size of approximately 15 km2, which, in the field has been found to indeed correspond to the suggested the sanitary zone no. 3 (the zone of observation according to the national legislation). Considering that karst spring is of ascending type, with a very stable discharge in the course of a hydrologic year, it is assumed that boundaries of its catchment area are not changing considerably throughout the year. Nevertheless, continuous monitoring of karst spring discharge and precipitation would provide a basis for more precise delineation of the catchment area as an iterative process.

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**Session Classification** : Parallel

**Track Classification** : Topic 7 - Karst Hydrogeology
Revealing groundwater flow systems on the basis of statistical spring data analysis

Friday, 27 September 2019 12:15 (15)

As conventional methods, spring hydro- and physico-chemographs are widely applied. With the help of these graphs, the local dynamics and heterogeneity of the aquifer can be investigated on catchment and aquifer scale. In turn, springs are the natural discharge points of flow systems, they can reflect the subsurface flow and temperature conditions, and therefore they can provide information about the groundwater flow pattern. Namely, the character of springs and their spatial distribution can be indicative for nested groundwater flow systems via the physicochemical parameters of their outflowing water, as well as for geothermal potential via their outflowing water volume and temperature. Similarly, to the groundwater flow pattern evolved in siliciclastic sedimentary basins, carbonate regions can also be characterized by regional subsurface flow field due to gravitational driving force on basin-scale.

This study intends to display the methodology of groundwater flow characterization based on springs via the case study of Hungarian hills and highlands, with special emphasis on the Transdanubian Range. It is located in the central part of Hungary and it consists of ~2-3 km thick carbonate formations and there are ~700 naturally discharging springs. Multidimensional data analysis of the springs as natural discharge points could help to understand the natural groundwater flow pattern and hydraulic role of structures. Elevation of spring orifice, water temperature, volume discharge of springs and major ion content as potential indicative parameters for groundwater flow were applied during basin-scale classification. Based on combined cluster and discriminant analysis (CCDA), groups were derived which were ranked into local, intermediate and regional flow systems.

Systematic analysis of springs can lead to a comprehensive conceptualization of groundwater flow systems and the consequent characterization regarding the geothermal potential of a carbonate area.

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Session Classification : Parallel

Track Classification : Topic 5.4 - Innovative approaches for understanding groundwater flow systems
Inter-disciplinary characterisation of carbonate reservoirs. ALBION, a multi-scales dynamic analogue.

Thursday, 26 September 2019 12:15 (15)

Carbonates probably host the most complex aquifers in terms of organisation of porosity networks and flow behaviour. Their heterogeneity originates at different scales and from numerous processes related to geology, hydrodynamics, chemistry and mechanic. These processes occur during a long-term history from just after the deposition of sediments to present day. At small scale, they provide the rock matrix with its petrophysical, mechanic and geophysical properties. At large scale, they can promote the development of karst networks or flow barriers.

The ALBION Project addresses the question of the relationships between the heterogeneity of carbonate reservoirs from pore to field scale and the heterogeneity of groundwater dynamics, which is induced. An interdisciplinary approach has been developed to tackle genetic processes and their impact on medium properties. Switching back and forth between in-situ multi-physics measurements and integrative modelling allow coupling interpretations and strengthening concepts used to populate reservoir models.

This innovative approach has been applied and enhanced on nested field sites in the Fontaine de Vaucluse catchment area (south-eastern France). The LSBB sector includes the so-called underground laboratory, an almost 4 km long tunnel, and three sets of boreholes drilled in the reservoir. It enables the investigation of flow behaviour for different media (matrix, fractures and karst) at various scales, in different well-known geological conditions and from different natural or experimental settings. Through a micro to meso-scale multi-physics characterization of matrix, relationships between geological, petrophysical and geophysical properties have been investigated, and an integrative classification of rock-types has been proposed. In the central sector of the catchment, near Saint-Christol-d’Albion, the karst network is well developed with several famous caves, as “Le trou souffleur”. In this area, factors controlling the genesis of karst conduits in the unsaturated zone have been investigated and a conceptual model has been proposed. Lastly, at the aquifer scale, integration of results acquired at lower scales added to numerous geological descriptions and analyses give new insights on the role and importance of the driving parameters of the evolution of the carbonate platform.

In next steps, other sites as the Lagnes-Robion quarry or a new tunnel in the LSBB will complete the disposal in this way. Finally, the assessment of porosity, permeability or geophysical properties of different rock-types at various scales will provide the framework to address the issue of upscaling in carbonates. Thanks to these different studies, a workflow of characterization and modelling has been established to investigate dynamic analogues.

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**Session Classification:** Parallel

**Track Classification:** Topic 5.1 - Dynamic Analogues
Models of Single-well Push-Pull Test with Mixing Effect in the Wellbore

Tuesday, 24 September 2019 16:00 (60)

The mechanism of solute transport around the wellbore was found to play an important role in the single-well push-pull (SWPP) test, but it was grossly overlooked in previous studies. For instance, the mixing effect of injected tracer with water in the wellbore was ignored in analyzing both injection and extraction phases of SWPP. In this study, new models were developed by including such a mixing effect in the wellbore. Two types of boundary conditions at the wellbore were considered: the resident concentration continuity (RCC) and the flux concentration continuity (FCC). To test the assumptions used in the mathematical model, the stochastic modeling, the numerical simulation and the laboratory-controlled experiment were executed. Results showed that the SWPP test was sensitive to the mixing effect in both injection and extraction phases. A larger wellbore volume could result in a smaller concentration at the late stage of the extraction phase. FCC was more reasonable in describing solute transport at the wellbore-aquifer interface than RCC, and the difference between them decreased with decreasing radial dispersivity. The MODFLOW/MT3DMS package contained an invalid assumption on the mixing effect for the SWPP test. Stochastic modeling demonstrated that the homogeneous assumption was a good approximation for the reality when the variance of natural logarithm of the auto-correlated hydraulic conductivity field was less than 0.25 ($\sigma_{\ln K}^2 \leq 0.25$). The laboratory-controlled experiment showed that the radial ADE model of this study worked well for the well-sorted sand aquifer.

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Session Classification: Poster with refreshments

Track Classification: Topic 5 - Tools, methods and models to study groundwater
Dynamic outcrop analogues in groundwater reservoirs. A disruptive approach for reservoir characterization and modelling.

Thursday, 26 September 2019 11:15 (15)

The usual workflow for delivering production forecasts for oil-bearing subsurface reservoirs consists in the building of very detailed geological and petrophysical models on which fluids flows are simulated. Populating models with heterogeneous distributions of reservoir properties is a very challenging issue because of the lack of data in typical datasets, that comprise boreholes with sparse lateral sampling, and seismic data with low vertical resolution.

Against this background of limited data, reservoir analogues have long been used to improve understanding of subsurface fields. From outcrops, geological data have been collected. Their interpretation has been used to build conceptual static models, and to run sensitivity studies of dynamic response to geological and petrophysical heterogeneity. Although quite advanced, this linear workflow does not achieve the objective of reservoir characterization as there is not any hydraulic information for calibration of the outcrop interpretation.

In the same time, hydrogeologists have developed observatories, dedicated to the observation and monitoring of groundwater reservoirs, for the exploitation of water resources and the prevention of environmental risks. These experimental sites provide data relevant to the understanding of the water cycle and the behavior of the aquifers. However, despite the acquisition of geological, geophysical and petrophysical data in boreholes, the description of geology is usually lacking in detail, thereby compromising the quality of the coupling between measurements, theories, and models.

A new concept of dynamic outcrop analogue arose from a double need: on one side, the integration of hydrodynamics and geophysics in outcrops studies, on the other side the use of detailed geology in observatories studies. The dynamic outcrop analogue allows the characterization of the reservoir at different scales and from an integrated point of view. The analogue is assessed through multi-physics experiments on various supports: outcrops, but also plugs, cores, boreholes and between wells, caves, tunnels... Coupling the hydrodynamic response of groundwater reservoir to a detailed static description of its heterogeneity very early before the building of models provides a key knowledge on the understanding of reservoir architecture. It contributes to improve the way models are populated and to enhance the forecast of reservoir.

This new methodology has been developed and tested through a pilot project, ALBION. The demonstration project is dedicated to the Urgonian carbonates (a barremo-aptian series outcropping in South-East France) and proposes a multi-scales set of analogues in the Fontaine de Vaucluse catchment area. On other sites, further projects are dedicated to various topics: multi-scales permeability in tidal sandstones, anisotropy of permeability in anastomosed fluvial channels, heterogeneity in unconsolidated alluvial coarse gravels, fractures and karstic networks, and permeability in a fault zone.

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Session Classification : Parallel
Track Classification: Topic 5.1 - Dynamic Analogues
Sequence stratigraphy as an inter-disciplinary tool for karst network forecast. Multiphase and multiprocess karst genesis in the Urgonian Formation.

Thursday, 26 September 2019 11:45 (15)

Commonly, in carbonate reservoirs, karst systems result from long-term, multiphase and multiprocess speleogenesis that can occur from very early after the sedimentation of the limestone to present-day geomorphological events. This leads to the construction of inherently complex karst networks with a piece of architecture difficult to understand and to accurately predict. The dynamic appraisal of these reservoirs gives greater insight into the overall organization of the actual karst systems, while totally ignoring the detailed features that impact the local fluid flow behavior. In order to reduce the uncertainties in predicting the behavior of complex systems, a reconstruction of the development of the karst conduits is needed. It requires that, for each speleogenesis stage, the processes and their controlling parameters are correctly assessed.

The issue of defining the prevalent parameters for the karst development is usually one on which the different specialists involved in the study of karst systems disagree. The difference in views is all the more important in the fact that specialists do not necessary address the question according to the karst origin (epigenic, hypogenic, island).

For geologists, lithology and geological structure impose a general control on most cave genesis. The karst is considered to be facies-controlled, with some rock fabrics and textures described as more favorable for the development of conduits than others. Faults and fracture zones influence the secondary porosity development, through karst enhanced fractures and highly developed cavern systems. However, lithologic and structural conditions for speleogenesis evolve throughout time and change from one phase to another: progressively, the importance of fabric-selective porosity and stratigraphic elements diminishes in favor of fracture porosity.

For hydrologists, hydraulic boundary conditions play as a controlling factor in karst genesis, as conduits develop mainly vertically in vadose zone and horizontally along the groundwater table, following the hydraulic gradient. Moreover, the hydraulic gradient can limit the extension or completely inhibit the development of horizontal conduits even if lateral flow path was structurally preferred.

In the Urgonian Formation, a cretaceous series outcropping in south-eastern France, the development of karst conduits has been considered through geological time, and examined from many different perspectives. For several stages of speleogenesis, the relationships between various geological and hydraulic drivers with the formation of karst features have been established. An integration of most drivers has been possible through sequence stratigraphy, which influenced both the development of pore and fracture systems, the extension of seepage areas, the evolution of water table, the organization of drainage networks, and the location of inception surfaces on sequence boundaries. Sequence stratigraphy appears as an impressive tool for proposing an integrated and predictive understanding of caves development. More generally, this study highlights how much karst genesis is a multi-factorial process, which requires an inter-disciplinary approach.
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Session Classification: Parallel

Track Classification: Topic 5.1 - Dynamic Analogues
Governance Status in Water Management Institutions in Barind Tract, Northwest Bangladesh - An Assessment based on Stakeholder’s Perception

Monday, 23 September 2019 17:30 (15)

Water situation in the drought-prone Barind Tract in the north-western part of Bangladesh is deteriorating day by day due to increasing demand of food production, urbanisation and industrialisation. Here balance situation between food and water security is a serious challenge to the policy makers. This study is undertaken in the southern part of the Tract to assess the existing status of water governance and to identify challenges of sustainable development. Both quantitative and qualitative methods were used to assess governance status in five water management institutes (WMIs) like Barind Multipurpose Development Authority (BMDA); Bangladesh Water Development Board (BWDB); Department of Public Health and Engineering (DPHE); Local Government and Engineering Department (LGED); and DASCOH Foundation - a non-government organization) selected purposively based on their activities in the area. Eight indicators like institutions, transparency, accountability, participation, social equity, environmental integrity, efficiency and effectiveness are taken into consideration and each indicator includes five sub-indicators. The overall governance situation of WMIs fall under ‘moderate’ category while DASCOH Foundation performs ‘good’, BMDA and LGED ‘moderate’, while BWDB and DPHE perform ‘bad’. Moreover BWDB and DPHE should look into the governance issue seriously and take a rigorous action plan for scaling up of governance status. On the other hand, BMDA and LGED apparently perform satisfactorily in governance issues but lag far behind in indicators like transparency, accountability, participation and social equity. In strategic plan, the DASCOH Foundation is trying to introduce noble concepts to institutionalise the Integrated Water Resource Management (IWRM) under BWA (2013) and disseminating models not only to the community and local government but also to the government sector. Moreover, there are significant gaps in coordination, technical capacity, transparency in project selection, implementation and citizen’s participation in WMIs. Finally actions to meet challenges such as implementation of IWRM in managing water resource; role rationalisation of water institutions and actors; updating and harmonising water laws to cope with existing challenges; enforcement and compliance of laws; establishing independent regulatory body and Water Resource Management Organization (WRMO) etc. will help managing water resources in sustainable manner.

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Session Classification : Parallel

Track Classification : Topic 3.1 - Groundwater and water security in developing countries
Groundwater runoff in small river basin: retrospective analysis and projections due to climate change

Monday, 23 September 2019 15:15 (15)

The analysis of the impact of observed and predicted climate variability on the total and groundwater runoff of the small river basin in humidal boreal conditions is considered on the basis of a physically based precipitation-runoff model. The model consists of two submodels. Surface precipitation transformations within a representative landscape element are simulated using the first SURFBAL submodel. It simulates the processes of snow accumulation on the surface of the earth, its melting during winter thaws and spring, the formation of surface runoff and potential ET, taking into account freezing and melting of soil cover. The results of the calculations are transferred to the second submodel, the groundwater flow model, as upper boundary conditions on the land surface for each landscape zone. The second model is based on MODFLOW2005 using the UZF package. This submodel calculates the flow rate in the unsaturated zone, groundwater recharge and ET, and the formation of surface and groundwater runoff within the basin.

In the first stage of the study, a retrospective analysis of the runoff in the studied basin was carried out on the basis of data on the dynamics of observed precipitation and temperature over the past 70 years. The results of this analysis have shown the long-term non-stationarity of the processes of total runoff formation, which is well in line with the observations of measured river runoff in the terminal gagging station. This non-stationarity is related to the increase in river flow and groundwater discharge in winter over the last 40-30 years due to the observed increase in winter temperatures.

At the second stage, the forecast calculations for the next 50 years have been carried out. For predictive simulation of precipitation and temperature series, the climatic generator LARS-WG was used, which generates time series of precipitation and daily temperature resolution based on forecasts of global circulation climate models from the CMIP5 family. For the forecasts 19 CMIP5 models were used.

The simulation results showed that the predicted groundwater runoff averaged over all climate models turned out to be more stable in the long-term and intra-annual section than the total surface runoff. The estimated intra-annual surface runoff hydrograph has changed in comparison with the retrospective period due to a decrease in the spring peak runoff of the river in the spring and an increase in winter runoff. The results of the forecast for different models from the CMIP5 family differ significantly. This is since all models predict a similar increase in the average annual temperature in the next 50 years. However, the predicted trends in annual precipitation vary greatly, from a 15-20% decrease in some models to a 20% increase in others.

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Session Classification: Parallel

Track Classification: Topic 2 - Groundwater and climate change
Assessment of groundwater vulnerability to pollution as part of integrated management in coastal. Case of Ghiss-Nekkour basin (North East of Morocco)

Thursday, 26 September 2019 16:00 (60)

Despite the fact that the Ghiss - Nekkour watershed is among the best-watered basins in North of Morocco, it suffers from various natural pressures. The entire region is vulnerable to various forms of risks including erosion, landslides, seismicity, intensive climatic changes, etc. These classical constraints are amplified by anthropogenic actions, mainly in terms of the tendency to overexploitation of water resource and the degradation of the quality of water, soils and natural areas, as a result of territorial mismanagement as a whole and the scarcity of water resources other than those of the Ghiss-Nekor groundwater. Given this general observations, an integrated management approach of the Ghiss-Nekor coastal basin seemed to be an important priority. For the development of such approach, our first reflection have led us to evaluate the vulnerability and the sensitivity of the Ghiss-Nekor groundwater to anthropogenic pollution using GIS and remote sensing. The first question that arises is: what approach should be used to assess the vulnerability and the sensitivity of the Ghiss-Nekor groundwater?

Many methods for assessing the vulnerability of groundwater against anthropogenic pollution have been developed in the past decades. However, if aquifer vulnerability concept is well defined and the methods have been constantly tested and compared, the problem of the choice of the best method remains. The choice of the method depends on a series of factors, including the scale of the problem, the hydrogeological characteristics of the area and data availability. From a pile of a vulnerability assessing methods, the GOD, DRASTIC and SI approaches have been the most extensively tested. This is why, in the present work, we applied them to evaluate the groundwater vulnerability of the Ghiss - Nekkour aquifer, located in North East of Morocco, on its Mediterranean shore.

The mapping resulting from the application of the three approaches shows a range of intervals divided into classes corresponding to fluctuating degrees of vulnerability from “very low” to “extreme”. The coincidence rate between the nitrate distribution of the groundwater and the mapped vulnerability classes is higher when the SI approach is applied.

Key words: Aquifer, GIS, Ghiss-Nekkour, Morocco, Remote sensing, Vulnerability.

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**Session Classification:** Poster with refreshments

**Track Classification:** Topic 8 - Groundwater quality and pollution processes
Water quality degradation and Nitrate source in the Massa catchment (Morocco), using $\delta^{15}$N and $\delta^{18}$O tracers

The Massa basin in Morocco suffers from water scarcity and water quality degradation largely due to salinity and nitrate contamination. In this study, a multi-tracer approach, was used that integrated water chemistry, stable isotopes of water ($\delta^{18}$O, $\delta^{2}$H) and stable isotopes of nitrate ($\delta^{15}$N, $\delta^{18}$O), to investigate mineralisation and nitrate contamination in the Massa catchment. The main objective was to identify, for the first time in the area, water pollution sources, with an emphasis on nitrate-originated contamination using the $\delta^{15}$N isotope. Water samples were collected from rivers, dams, wells, boreholes and springs, from different parts of the area (irrigated farms, along Massa River, Anti-Atlas Mountains and coastal areas). The results show a large variability of water mineralisation in space indicating rock-water interaction, sea-water intrusion and anthropogenic influence. The lowest mineralization value is measured in spring water located in the Anti-Atlas Mountains while the highest one is measured in Massa River. The results also show a large variability of NO3 with high contents in many sites. Some domestic wells showed the highest NO3 concentrations. The field investigation reveals a practise where domestic wastewater is being poured directly into traditional septic tanks. $15N$ results indicate mixing origins of nitrate related to sea-water intrusion, NH4 fertilizers and manure septic which constitute the main issue. Our results will be an essential recommendation for decision-makers for the implementation of wastewater treatment systems before they are discharged into the environment. Improving individual septic systems is also a necessary condition.

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Session Classification : Parallel

Track Classification : Topic 8 - Groundwater quality and pollution processes
Towards water quality management of an urban pond supported by nutrient rich groundwater

Tuesday, 24 September 2019 16:00 (60)

Urban ponds are playing an important role not only as a nexus between nature and city residents but also as precious habitat for wild lives in urban settings. It is often the case that nutrient rich groundwater is the only available water source for the ponds. Water quality degradation due to eutrophication has often been reported in such ponds, resulting in excessive bloom of green algae accompanied by unpleasant smell during summer seasons. In order to prevent algae blooms, the nutrient concentrations in the pond water needs to be properly controlled and managed.

We evaluated sources and factors that affect nitrate and phosphate concentrations in Pond Junsai which is an urban park pond situated approximately 10km east of Tokyo in a highly populated area. The purpose is to find an effective way to manage the water quality using nutrient rich groundwater.

Pond Junsai consists of 6 small ponds having total surface area of 2.2x10^4m^2 and watershed area of 3.7x10^5m^2. Air photo analysis indicated that impermeable area in the watershed was 4.4% in 1947 and has increased up to 71.3% in 2013 due to urbanization, resulting disappearance of spring water which used to support the pond. Having no influent stream, the pond has been fed by precipitation and groundwater pumped up from multiple wells since 1979. Currently inflow to the pond consist of 67% groundwater and 33% precipitation. Approximate turn over time is 51.2 days.

The groundwater from multiple wells have various but high either nitrate or phosphate concentrations depending on the depth of the screens. Precipitation, groundwater and waterfowls are main nutrient sources to the pond and account 9%, 72% and 17% of nitrate load, and 6% 57% and 37% of phosphate load, respectively. Annual nitrate load to the pond was estimated to be 266.0kg/year, whereas phosphate load was 126.3kg/year. Budget calculation indicated at least 126.3kg of nitrate is consumed in the pond, whereas 8.3kg of phosphate is produced/released within the pond annually.

Several counter measures to reduce nutrient concentrations were experimented in 2017 and 2018 within a small part of the ponds. Draining and drying a pond reduced the phosphate concentration while it increased the nitrate concentration after rewatering. Air bubbling caused sediment disturbance, which increased phosphate concentration. Clearing the flow passage and shortening the residence time was found to be effective to reduce both nitrate and phosphate concentrations, which lead to success in preventing algae bloom during summer of 2018. An attempt to control N/P ratio which affects algae bloom by changing mixing ratio of groundwater from different depths is currently in progress.

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Session Classification : Poster with refreshments
Track Classification: Topic 6 - Groundwater, wetlands and natural heritage
Groundwater Modeling in Integrated Water Resources Use in the Little Akaki Watershed, Ethiopia

Integrated use of surface and groundwater resources is essential to provide reliable water supply and to sustainably manage the water resources. In the Akaki watershed, groundwater pumping contributes for more than 25% of the water supply to Addis Ababa City, the capital of Ethiopia. The groundwater abstraction is significantly increased without reliable quantification of hydrologic and hydrogeological components of the water resources. In view of that, this study applied the SWAT model calibrated with SWAT-CUP for surface water simulation and MODFLOW model for groundwater simulations. The MODFLOW was calibrated using the water table and baseflow. Using the two models the surface water and groundwater potentials in the Little Akaki sub-basin under different recharge (change based on land use change) and pumping scenarios were analyzed. The combination of the two models, SWAT and MODFLOW models successfully estimated the surface water and groundwater resources and the results found were acceptable.

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Session Classification : Parallel

Track Classification : Topic 1 - Groundwater assessment and management
Interaction and connectivity of stream water with groundwater in Wangjeon-ri WCC (water curtain cultivation) area, Nonsan, Korea

Monday, 23 September 2019 16:00 (60)

Since 1984, Korean WCC area has been spread rapidly. Annual groundwater use in WCC area has been estimated to be 5.4~5.7 m³/y, which is equivalent to 32~35% of agricultural groundwater use in Korea. The WCC usually begins at November and ends at March every year. Therefore, every year starting from November, groundwater level in WCC area gradually declines and reaches to its lowest level at March. Thus, one of problems related to WCC in Korea includes severe shortage of groundwater resources during the peak season. Because nearby stream water is definitely introduced into the aquifer system due to much lower level of groundwater compared to stream water during WCC peak time, it is likely that the problem can be resolved efficiently if the connection characteristics between groundwater aquifer and stream water are well understood. In order to understand the connection between stream and ground water, and the influence of stream water on the nearby aquifer, this study examined temperature, and oxygen/hydrogen stable isotopic compositions for both stream and ground water extracted from wells. This study was performed at Wangjeon-ri of Nonsan City, which is one of well-known strawberry WCC areas in Korea. The study area covers about 1.2 km² in which about 74% of 291 vinyl house used to be applied for WCC. Water sampling was done during February 2010 through June 2011. Groundwater temperatures for 51 wells were measured to be ranged from 9.8 to 16.3 °C, and mostly 14.6 °C. Inflection point for water temperatures was identified at the zone of 140 m to 160 m distance from the stream, which might be inferred to be range of intensive intrusion of stream water into aquifer. Overall temperature distribution pattern indicates that Noseongcheon stream water widely intruded into the surrounding aquifer and affected groundwater temperature obviously in the southern right part of WCC area. However, in the southern left part, the influence of stream water into aquifer seems to occur in very narrow restricted range near the stream. This phenomenon can be similarly found by the oxygen and hydrogen isotopic data. There are two possible end members affecting water quality in aquifers beneath WCC area; groundwater in the northern rolling hill part (δ¹⁸O = -7.71 ~ - 7.59 ‰ (-7.62 ‰ in average), δD = - 54.1 ~ - 53.7 ‰ (-54.9 ‰ in average)) and Noseongcheon stream water in the southern area (δ¹⁸O = -6.86 ~ - 6.66 ‰ (-6.74 ‰ in average), δD = - 49.7 ~ - 47.8 ‰ (-48.1 ‰ in average)). The average values can be used for estimation of mixing ratios in each point of WCC area between stream water and groundwater recharging from northern rolling hills.

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Session Classification : Poster with refreshments

Track Classification : Topic 1 - Groundwater assessment and management
Study on the groundwater quality management in unconfined aquifers of rural areas, South Korea

Monday, 23 September 2019 18:15 (15)

The purpose of this study is to investigate the cause of groundwater contamination in the selected study areas and to propose the appropriate management plans for the drinking shallow groundwater in agricultural areas. The study areas were selected in 2014 and 2015 with consideration of the groundwater quality, field survey and hydro(geo)logical factors. For five years (2014-2018), we have been monitoring the groundwater quality, analyzing the hydrogeological characteristics, and investigating on-site contaminant sources in the study areas.

In the study area 1, the organic fertilizer used in the field was investigated as the main source of groundwater contaminants. We have managed the use of organic fertilizer since 2016 and installed the new groundwater wells in the weathered vadose zones and weathered rock layers to improve the groundwater quality and supply the safe groundwater. The result showed that high NO3-N (>20 mg/L) concentrations in some wells have decreased with time. However, the contaminant concentrations of the newly installed groundwater wells showed no significant variations during the study period. It implies that the shallow aquifers have been heavily contaminated by the non-point contaminant sources mainly located in the vadose zones.

In the study area 2, the groundwater deterioration was investigated by the excessive use of organic fertilizer and livestock manure accumulated throughout the field. Relatively deep-groundwater wells (approximately 100 m drilled from the ground surface) and direct groundwater supply system were proposed and applied to provide the safe and drinkable groundwater in 2016. In order to analyze the characteristics of groundwater quality changes after removing the point contaminant source of livestock manure in October 2017, the monitoring wells were installed in the downstream direction of groundwater flow from the point sources. Despite of removing the point sources, the NO3-N concentration of monitoring wells showed no significant variations. The contaminant concentrations, however, increased when the groundwater level rose in the study area. Therefore, more time to monitor is needed to evaluate the test bed for the point source control.

As the result of this study, various action plans such as (non) point contaminant source controls and so on, are needed for improving groundwater quality. This whole process should be performed by the comprehensive management plans, which are based on evaluating and estimating groundwater quality status and characterizing the detailed hydrogeological setting in the agricultural study area, and so forth.

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Session Classification: Parallel
Track Classification: Topic 1 - Groundwater assessment and management
Many landfills do not have ground seals, so that pollutants leached from waste migrate to the ground and water environment. In most cases, the exploitation of unsealed landfills has ended; however, their impact on the groundwater environment still occurs. Lysimeter studies allow us to determine the size and chemical composition of leachates as well as the leachate water balance. The lysimeter experiment was carried out from November 2016 until May 2017 on a 230-litre municipal waste sample. During the experiment, the lysimeter was precipitated with distilled water. In each month of the experiment, the total volume of the obtained effluents was measured and the values of specific electrolytic conductivity, temperature, pH and Eh were determined. In addition, the characteristic indicators of groundwater pollution in the area of municipal waste landfills (Na, K, Ca, Mg, Fe, Al, Mn, Ni, Cu, Sr, S, Cl, SO4, HCO3, NO3, NO2, NH4, PO4, N Kjeldahl, TOC) were monitored. Microbiological analysis and profiling of physiological population level using EcoPlateTM microarrays - were also performed in collected leachate samples. The maximum EC value from leachate from the lysimeter was 33 mS/cm. High concentrations of ammonium ion (up to approx. 1400 mg dm-3), chlorides (up to approx. 6800 mg dm-3) and iron (up to approx. 31 mg dm-3) were observed in the effluents. Microbiological analyses showed strong contamination of leachates with bacteria, including potential human pathogens. Community-level physiological profiling indicates that the activity and functional diversity of microorganisms were higher in the samples obtained in winter compared to leachates collected from lysimeters in spring.
Teleconnections between NAO, EA, and SCAND and groundwater levels in Portugal

Monday, 23 September 2019 15:45 (15)

This study examines the teleconnections between the North Atlantic Oscillation (NAO), East Atlantic (EA), and Scandinavia (SCAND) climate patterns and groundwater level fluctuations in Portugal. Precipitation and piezometric records (1987–2016) from two aquifer systems, Leirosa-Monte Real in the north and Querenca-Silves in the south, are analyzed using wavelet transform methods and singular spectral analysis. The capacity of wavelet transform methods to analyze processes at various scales exposes not only the impacts of climate modes (NAO, EA and SCAND) but also the existence of complex transitive couplings among modes. Extreme events coinciding with coupled phases mark sharp boundaries in mode interaction patterns or sudden shifts in the time-frequency space. Groundwater levels over the analyzed time interval display consistent relationships with climate indices in distinct period bands and time windows. The strongest covariability occurs in the 6–10 years band for NAO, in the 2–4 years band for EA (especially after 1999) and in the 4–6 years band for SCAND (especially after 2005). Episodes displaying simultaneously multiple coherent relationships are associated with coupled phases among NAO, EA and SCAND. The results indicate that NAO, EA and SCAND patterns together are responsible for most (80%) of the inter-annual variability of groundwater levels in Portugal. NAO is the first leading pattern of variability, accounting for 40% and 60% of the total variance of groundwater levels in the north and south of the country, respectively. The joint contributions of EA and SCAND account for the remaining 40% of variability in the north and 20% of variability in the south, on average. Monthly groundwater levels averaged over years of positive and negative phases of climate indices provide additional insights on the influence of coupled patterns. Combined winter NAO-EA+ phases are associated with maximum groundwater levels while combined NAO+EA− phases are associated with minimum levels. Further understanding on how climate modes influence groundwater storage can improve future projections of groundwater availability and guide integrated water resource management practices not only in Portugal but around the world. This work is supported by FCT-project UID/GEO/50019/2013 – IDL.

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Session Classification : Parallel

Track Classification : Topic 2 - Groundwater and climate change
Characterization of aquifer heterogeneities by integrating tomographic pumping tests and flowmeter data

Thursday, 26 September 2019 12:30 (15)

The accurate characterization of the depositional structure and hydraulic properties is essential to understand flow and solute transport in porous heterogeneous rocks. Hydraulic tomography was shown to be an efficient technique to provide information on the spatial distribution of hydraulic properties in heterogeneous rocks. Due to information about the 3D sedimentary structures is often not available, most of existing field applications of hydraulic tomography relays on either horizontal or vertical two-dimensional forward models to invert head and/or flow data. In this work, we explore the potential of combining tomographic pumping and flowmeter tests for characterizing aquifer heterogeneity in 3D. We propose a framework for inverting drawdown data with a constraining structure constructed from the interpolation of single-well flowmeter profiles to infer aquifer structure and transmissivities. The inverse model is first validated for several synthetically generated hydrogeological models with complex depositional structures and heterogeneous hydraulic properties within each unit. It is shown that with the constraining structures informed by the flowmeter profiles, the inverted model exhibits realistic depositional features while maintaining an acceptable fitting between the simulated and measured head data. We then apply the method to characterize the sedimentary structure and transmissivities of a real experimental site drilled in layered porous rocks with complex dune structures. The inverted aquifer geometry is in a good agreement with field characterization on outcrops and cores while the main flow direction of the simulation model is also congruent to field measurements.

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Session Classification : Parallel

Track Classification : Topic 5.1 - Dynamic Analogues
Characterization of horizontal permeability anisotropy in heterogeneous porous rocks: a comparison of tensor detection methods with synthetic and field datasets

Thursday, 26 September 2019 16:00 (60)

The characterization of heterogeneous porous rocks is an important task for many applications, including aquifer management, oil field development and environmental protection. When applying the traditional approaches based on single-well hydraulic tests to estimate the hydraulic parameters of porous formations, the estimation is often erroneous. The main reason of the failure is that all these single-well methods assume that the subsurface system can be represented by one or at most a few isotropic homogeneous hydraulic units. However, in reality preferential flow directions often occur in natural porous systems due to the presence of complex depositional geometries. Thus, significant permeability anisotropy exists. To achieve an enhanced characterization, hydraulic interpretation approaches based on information from multiple testing wells are required.

In this work, we present a review and comparative study of several methods for detecting aquifer anisotropy. These methods were developed based on different types of hydraulic configuration, such as pumping and slug tests. Depending on the formulation, either based on analytical calculations or graphical fittings, their utilizations are of different levels of complexity. To make quantitative comparison, the various methods are applied to analyze 1) a synthetically generated hydraulic dataset, and 2) a real dataset collected from a field experimental site in a layered shell carbonate with complex dune structures. We discuss the implications of applying these methods in real practice in terms of their effectiveness (i.e., the accuracy of the results) but also their efficiency (i.e., the time spent in applying the method), and offer guidance for the selection of the optimal method based on a variety of realistic constrains.

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Session Classification : Poster with refreshments

Track Classification : Topic 5.1 - Dynamic Analogues
Influence of stress on incipient karst generation in natural fracture networks

Thursday, 26 September 2019 11:15 (15)

We develop a new numerical model that couples hydraulic, mechanical and chemical processes to investigate the dynamic influence of stress on incipient karst formation in natural fracture networks. Our geological models are constructed based on realistic fracture patterns mapped from outcrops, which capture a wide range of spatial distribution and organization of carbonate fracture networks. We simulate the dissolutional growth of karst conduits in the fractured formation under varied initial aperture distribution and in-situ stress loading. We found that the importance of the stress effect on karstification depends on the relative relationship between the flow direction and structural anisotropy of the fracture network. When the flow occurs in the direction of main network structures, karst conduits only develop locally along a few large fractures with a preferential orientation for frictional sliding under the differential stress due to enhanced transmissivity caused by the important shear-induced dilation. In contrast, when flow is in the direction transverse to the main fractures, the far-field stress loading has a negligible impact on the emergent dissolution pattern while only impact on the onset time of breakthrough. In this case, the developed conduits are much more tortuous with many branches. In both cases, the presence of initial aperture variability facilitates the development of a dissolution front and therefore makes breakthrough faster. Our results demonstrate that the heterogeneity induced by geometrical complexities and in-situ stress conditions may play a decisive role in the karstification processes in fractured rocks. The results from this research provide important insights into the spatial relationship between tectonic structures and karst cavities, which has important implications for karst aquifer management and related environmental protection, or hydrocarbon production in fractured carbonate reservoirs.

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Session Classification : Parallel

Track Classification : Topic 7 - Karst Hydrogeology
Lessons learned from groundwater governance and management and capacity building programmes in the developing world

Monday, 23 September 2019 11:45 (15)

Sustainable groundwater management has become topical and thrust in the forefront of water resources development and management in recent years, buoyed by the increasing water scarcity resulting from recurrent droughts, over-exploitation and quality deterioration of groundwater resources, especially in semi-arid and arid countries of the developing world. Climate variability and change further acerbates the impact of unsustainable use and abstraction of groundwater. There is, therefore, utmost need to support developing countries water management and governance institutions to better their understanding and implementation of sustainable groundwater management.

Technical support and capacity building in groundwater governance and management towards sustainable groundwater use and abstraction was provided to different developing countries through various programmes of the Gesellschaft für Internationale Zusammenarbeit (GIZ) over the past two decades, which included: (i) SADC Transboundary Water Management Programme - Botswana, (ii) Rehabilitation of Water Supply Systems in Western Eritrea Programme, (iii) Water Sector Reform Programme in Kenya; (iv) International Water Stewardship Programme in Pakistan and Zambia, and (v) Reform of the Water Sector and Urban Water Supply and Sanitation Programmes in Zimbabwe. A detailed account of these programmes is provided concomitantly with its objectives, achievements and lessons learned.

Groundwater governance of each of the regions (Southern Africa: Botswana, Zambia and Zimbabwe; Eastern Africa: Eritrea and Kenya and Southern Asia: Pakistan) is compared and its impact on sustainable groundwater management evaluated with the aim to identify future governance needs and required support.

The analysis shows that there are more similarities than differences in the shortcomings of groundwater governance and that mitigation of the shortcomings requires interventions adapted to the local circumstances. There is a critical need for developing and operationalizing legal frameworks, and strengthening of the institutional frameworks.

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Session Classification : Parallel
Track Classification : Topic 3.1 - Groundwater and water security in developing countries
Characterization of forest fire ashes as a source of groundwater pollution. The fire of Doñana natural space 2017

Thursday, 26 September 2019 16:00 (60)

In June 2017, a forest fire in Moguer (Huelva) calcined more than 8400 ha of pinewood and scrubland. Large areas of the Doñana National Park were affected and the burned terrain included stone pine, juniper, eucalyptus and mediterranean scrub. The fire not only caused the destruction of vegetation and fauna but also liberated pollutants to the atmosphere and to the surface waters. The ashes and combustion residues altered the surface layer of the soil and released a large amount of solutes that were immediately available to be leached by the rains. This work shows the quantitative and qualitative characterization of the water soluble fraction obtained from the fire ashes. It also shows the composition of the soil layer extracts in direct contact with the ashes, as well as the 2-metre-deep probes. It has been observed that the ashes cause a remarkable alkalinization of the soil extract and an increase of the electrical conductivity of up to 440 times the initial values. Moreover, there is also a strong increase in the amount of soluble arsenic. Additionally, it also highlights the release of soluble phosphorus, the presence of reduced forms of nitrogen, which in natural conditions are not observed, and a significant increase in soluble silica. However, due to the scarce mineralization of the extracts, the study of major elements as possible index of affection to the soil, is not considered appropriate.

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Session Classification : Poster with refreshments

Track Classification : Topic 8 - Groundwater quality and pollution processes
First results to model statistical karst networks using seismic faults and an original sub-seismic faults statistical model: a study of uncertainty impacts on flow.

Thursday, 26 September 2019 16:00 (60)

Modeling flow in karst network is an important topic for Brazilian pre-salt carbonate reservoirs. The karst networks are studied using hypogene karst analogue systems (Cazarin et. al. 2016), seismic data and well logs. The karst networks are related to fault networks and super K layers. A main difficulty is to build a statistical model to characterize the karst impact on flow. Verscheure et al. 2012 proposed an approach to characterize the fault network and to model the sub-seismic faults keeping a geological consistency of seismic faults. This approach captures the spatial fault organization thanks to a fractal dimension. A stochastic algorithm based on multiplicative cascades (Darcel et al. 2003) is then used to generate the sub-seismic faults. An advantage of this approach is that it is well suited to be used with gradual deformation method (Hu 2000) to resolve an inverse problem. Stochastic karst networks are derived from these faults network and from high permeable reservoir layers (super K layers). The poster presents a fault analysis based on a reservoir fault network. Karst networks are built using Verscheure’s approach and unit layers. The results show an uncertainty on fractal dimension. The impact of this uncertainty is characterized in term of karst network geometries and in term of impact on flow anisotropy. These results highlight the importance of using multi-disciplinary approaches in the process of modeling flow in karst systems.


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Session Classification : Poster with refreshments

Track Classification : Topic 7 - Karst Hydrogeology
Squaring the cycle of groundwater processes in nutrient budgets: a socio-hydrogeological application in the Lombardy Plain (Italy)

Monday, 23 September 2019 12:00 (15)

Nutrient processes in groundwater are a well known – and widely studied – issue, often contributing to aquifer contamination in densely populated areas worldwide. Nevertheless, stakeholders now almost assume that the problem is not only present, but also difficult to resolve, despite the scientific and political efforts. Therefore, nitrate contamination is almost set aside, compared to new issues, such as emerging pollutants.

The Lombardy Plain (Italy) is an area highly affected by nitrates contamination, due to the coexistence of intense agricultural, livestock farming, industrial sites and urban sprawling, and a complex multilayer aquifer system.

Recent studies demonstrated that despite the thirty-year efforts to implement the European Nitrate Directive, groundwater nitrate contamination is still a serious threat potentially affecting up to 9,000,000 inhabitants, with most monitoring wells showing steady or increasing NO3 concentrations. Results hence shows that the adopted strategies are not effective, and that a new approach is required to solve this issue, taking into account both the complexity of the hydrogeological system and the socio-economic context that triggers nitrate contamination. For this reason, a socio-hydrogeological approach was adopted in the frame of the INTEGRON project (Cariplo Foundation, grant number 2015-0263), whose overall goal is to integrate the role of groundwater as sink or source of nutrients (N and P) in river basin mass balances. A classical hydrogeological and hydrogeochemical approach was adopted for aquifer characterization, to understand the timing of nutrient transfer from and to the surface, and to identify the main contamination sources. Groundwater modelling was used to obtain long term projection of the evolution of nutrients concentrations in the system.

In addition, tools and analyses typical of social sciences were integrated in the study. A Social Network Analysis was performed at the beginning of the investigation permitting to unveil the social structure of the studied area, and to highlight both social factors and key stakeholders that would determine the success of the implementation of the new science-based actions resulting from the hydrogeological investigation outcomes. To ensure a more comprehensive understanding of the needs and emergencies faced by local water users, public engagement activities were undertaken, targeted to both capacity building and outreach. The administration of semi-structured interviews and results dissemination fostered the creation of a network of mutual trust between farmers and the research team. Finally, all the recommendations resulting from the project were discussed in an open meeting with local stakeholders, to ensure a consensus on the proposed guidelines, thus combining bottom-up and top-down approaches for water resources management.

Prior to this investigation, socio-hydrogeology was mainly implemented in developing countries. Results of this project demonstrate the effectiveness of a such approach to support regional groundwater governance also in European contexts.

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**Session Classification**: Parallel

**Track Classification**: Topic 1 - Groundwater assessment and management
Application of hydro-geophysical monitoring method to identify the flow path of CO2 and gas tracers injected in shallow aquifer system at K-COSEM site, Korea

Artificial CO2-infused groundwater injections into a shallow aquifer system have been performed twice since 2014 by K-COSEM research group at a site in Eumseong, Korea, which was specially constructed to study environmental impacts of CO2 leakage on shallow aquifer system. The first injection was performed for 6 hours (short-term injection) as pulse-type leakage of CO2 under a natural hydraulic gradient (0.02) imitating point leaking situation along vertical preferential pathway such as fracture or crack in an injection pipe. In the second injection, CO2 was continuously injected for 30 days (long-term injection) under a forced hydraulic gradient (0.2) considering CO2 leakage events that can be happened in wide-ranging areas. CO2-infused and tracer gases dissolved groundwater were injected below groundwater table through a well, and various monitoring methods were employed not only for saturated but also for unsaturated zones. As parts of this monitoring, hydro-geophysical monitoring has been applied to identify the flow path of injected CO2 and gas tracers and to trace the temporal and spatial distribution of CO2 plume. CO2 concentration is monitored in real time using a non dispersive infra red (NDIR) sensor and an open loop-air purging (OL-AP) system. Temperature and hydraulic parameters (pH and EC) were also collected while, several gas tracers (He, Ar, Kr, SF6), total inorganic carbon (TIC) and carbon isotope (δ13C) were periodically measured. Further, time-lapse (TL) 3D electrical-resistivity (ER) surveys were also performed at before, during and after the injections. Hydro-geophysical monitoring results for the short-term injection showed that injected CO2 migrated along the preferential pathway identified through hydraulic interference tests. On the other hand, TL 3D ER surveys for the long-term injection test showed that CO2 plume migrated along the direction of the ground water flow, while gas tracer data as well as geochemical data such as pH, EC and pCO2 indicated that the migration of CO2 plume was well controlled by the forced hydraulic gradient. The monitoring results indicated that detection of CO2 leakage into groundwater was more effectively performed by using a hydro-geophysical method in order to capture by-passing plume. With this concept, the direct injection of CO2 gas into a shallow aquifer system was proposed. The injection and monitoring tests at the K-COSEM site indicated that CO2 leakage or by-passing CO2 plume in groundwater can be more effectively detected under a monitoring system based on hydro-geophysical method.

Financial support was provided by the “R&D Project on Environmental Management of Geologic CO2 storage” from the KEITI (Project number: 201800181002) and the National Research Foundation of Korea (NRF) grant funded by the Korea government (MSIT) (NRF-2018R1C1B6007390).

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Session Classification : Parallel
Track Classification : Topic 5 - Tools, methods and models to study groundwater
Natural and anthropogenic factors influencing the groundwater chemical composition of the upstream part of the Oredezh river valley (St.Petersburg Region, Russia)

Thursday, 26 September 2019 16:00 (60)

The studied area is located in the Northwestern part of the Russian Platform. The sedimentary cover is formed by 500 m thick Paleozoic and Quaternary rocks. There are three main aquifers: the Mid-Devonian and Quaternary (QIII-IV+D2st) unconfined aquifer used for local water supply of the villages; the Mid-Devonian (D2nr) confined aquifer of no practical importance, and the Ordovician (O1-3) confined aquifer used for public water supply of the bigger settlements and towns. Groundwater chemical composition of the studied area is rather well investigated due to the annual summer fieldworks carried out by lecturers and students during the field training on geology and hydrogeology. Data on major component composition and contents of nitrogen compounds for three aquifers have been collected and analyzed since 2005. ANOVA, regression and correlation analyses have been applied for the description of long-term variations of the groundwater quality.

Variety in the groundwater chemical composition of the Mid-Devonian and Quaternary aquifer (QIII-IV+D2st) is partly caused by the host rock composition, which is different due to the complicated geological history of the area. Climatic factors, especially amount of precipitation, are also of great importance. One more significant factor is agricultural activity of the local people and presence of the poultry factory in the close proximity from the studied area. This factor mainly influences the presence of groundwater contaminants, such as nitrates, nitrites and ammonium.

The chemical composition of two deeper confined aquifers remains more stable in time and mostly depends on the host rock types. The initial degree of nitrate contamination is sometimes observed in the Ordovician aquifer, probably, due to the poor isolation of the well heads.

In 2018, samples of different kinds of Quaternary host rocks were collected and analyzed to understand the origin of the groundwater natural composition. Results obtained were processed by statistical methods. Water samples have also been collected and analyzed to supplement the existing database and to continue the row of the regime observations. Thus, influence of water-rock interaction, amount of precipitation and human activity to the groundwater chemical composition will be shown.

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Session Classification : Poster with refreshments

Track Classification : Topic 8 - Groundwater quality and pollution processes
Contrasting the behaviour of karstic and non-karstic hydrologic processes at the catchment scale

Thursday, 26 September 2019 11:45 (15)

Large-scale hydrologic models exist for prediction and management of water resources. These models typically do not explicitly consider the particularity of karst hydrology, which is crucial to capture the characteristics of hydrologic responses in karst regions. Most of the studies in karst regions focus on recharge areas and karst spring systems at the aquifer scale. Few studies have investigated the interaction of karst springs and streams at the catchment or even larger scales. Therefore, how to adequately combine karstic and non-karstic characteristics in model still needs to be understood. In this study, we introduce a systematic approach for conceptual model development at the aquifer and catchment scales to investigate appropriate model structure(s) that integrate karstic and non-karstic properties. Firstly, six pilot catchments around Europe and Mediterranean have been selected to implement the approach. Every pilot catchment has both streams and karst springs with discharge observations over 10 years. These pilot catchments are small to large size with low to high karst coverage and cover different landscapes and climates. We use a new observation-based approach to develop a conceptual model as a specific guidance for the selection of the most appropriate numerical model structure(s). In order to combine surface catchment and recharge area, the calculation of a new metric, the Lateral Flow Index, is necessary to quantify differences between topographic and subsurface catchment areas. Finally, based on the conceptual model, we will explore the most appropriate model structure(s) that account for the identified relevant processes of our test sites. We benchmark the usefulness of our results at the catchment scale by comparing them with the results of an existing HBV model that does not explicitly include karst features. This study will give insights to the knowledge gap of the combination of karstic and non-karstic hydrologic processes into one model and will provide directions for modelling water resources availability at karst regions at a large scale.

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Session Classification : Parallel

Track Classification : Topic 7 - Karst Hydrogeology
Hydrogeological modelling for the watershed management of the Mar Menor coastal lagoon (Spain)

Tuesday, 24 September 2019 12:15 (15)

The Mar Menor is the largest lagoon along the Spanish Mediterranean coast. It suffers from eutrophication and algal blooms associated with intensive agricultural activities and urban pressure in the surrounding Campo de Cartagena plain. A balanced discharge of groundwater, carrier of algal nutrients such as nitrate, is essential to ensure the integrity of the coastal lagoon and the availability of groundwater resources inland. In this work, we present a 3D hydrogeological model of the unconfined Quaternary aquifer that discharges into the lagoon. The model couples both surface water balance and groundwater dynamics and has been calibrated to available data in the period 2000–2016. The calibrated model allows understanding of the current state of the aquifer and its link to the lagoon. The potential discharge has been quantified in both space and time and falls between 69.5 and 84.9 hm3/yr during dry and wet periods, respectively (with values of nitrate discharge of 11.4–11.8 Mkg/yr in the absence of aquifer sink terms, e.g., leakage to deeper aquifers and pumping from groundwater wells). The predictive capabilities of the calibrated model can be used to test the impact of different integrated management scenarios on the surface-groundwater dynamics of the catchment. Three plausible management scenarios are proposed that include localized and distributed groundwater pumping (drains and groundwater wells, respectively). Results show the effectiveness of the scenarios in reducing the groundwater and nitrate discharge into the lagoon. The disadvantages of the proposed scenarios, including potential seawater intrusion, need to be balanced with their relative merits for the sustainable development of the region and the survival of the Mar Menor ecosystem. The modelling approach proposed provides a valuable tool for the integrated and holistic management of the Campo de Cartagena-Mar Menor catchment and should be of great interest to similar hydrological systems with high ecological value.

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Session Classification : Parallel

Track Classification : Topic 1 - Groundwater assessment and management
Groundwater quality in the foothills of the Crimean mountains

Thursday, 26 September 2019 16:00 (60)

The Crimea Peninsula is located at the south-west of the East European Plain. The Crimean Mountains occupy the southern part of the peninsula and stretch for 180 km from east to west. Tectonically, this is a part of the Crimea-Caucasus mountain system. The elevations vary from 250 to 1500 m.

The studied area is situated within the second (inner) ridge of the Crimean mountains, in the mid-stream of the river Bodrak (near the village Trudolyubovka), where there is a unique geological training site of St.Petersburg University existing for nearly 60 years.

The average annual temperature of the area is about 11,6 °C (at present, there is a trend of temperature increase of 0,37/10 years). Negative anomalies of mean monthly air temperatures are associated with periods of dominance of the north-east winds.

The study area is divided into the following zones and aquifers: Quaternary aquifer (Q); Lutetian aquifer (Pg2lt); Danish aquifer (Pg1d); Hauterivian aquifer (K1(v-h)); water bearing zone of Karadag series (J2b). Unweathered sediments of Karadag, Eskiorda and Taurian series (J2b) form the regional aquitard.

Groundwater developed in the study area mostly belongs to zone of active water exchange. Only the water in fissures and veins of Karadag volcanic-sedimentary series (northern part of the village Trudolyubovka) belongs to the deeper zone. Groundwater of the Bodrak river basin is of meteoric origin (685 mm a year is a middle precipitation value of the river catchment), as well as of transit water and condensation genesis. About half of the total precipitation value is spent on evaporation and transpiration. In the warmer months, the groundwater resources are replenished by condensation, which is estimated as 2 % of the precipitation, it is 11 mm a year (condensation module is 1.85 l/sec·km2).

The predominant ions of all natural waters are mostly HCO3- and Ca2+. Migration forms of chemical elements have been studied and the balance of carbonate and sulfate compounds in groundwater has been calculated using the PHREEQC Interactive 2.15.0 software. Most of the water samples are in equilibrium with calcite and dolomite.

Since 1998, monitoring of water quality is carried out every summer. In summer, the local people experience serious problems with both the quantity and quality of freshwater. Water from private wells often does not meet the quality standards for drinking water (SanPiN 2.1.4.1074-01) on a number of parameters (hardness, TDS). There are high concentrations of nitrates (up to 250 mg/l) in groundwater of some of the residential areas. The water from the water intakes usually meets the quality standards, but, there are serious problems of water shortage in summer due to mismanagement and unsustainable water use.
Track Classification: Topic 8 - Groundwater quality and pollution processes
Remote Sensing for Monitoring and Mapping Karst Groundwater Flooding in the Republic of Ireland

Monday, 23 September 2019 15:30 (15)

Karst related groundwater flooding represents a significant hazard in many rural communities in Ireland. A series of unprecedented flood events in recent years have reinforced the need to improve our ability to quantify the location and likelihood of flood occurrence. Geological Survey Ireland, in collaboration with Trinity College Dublin and Carlow Institute of Technology, has established a collaborative project to investigate groundwater flooding, with particular emphasis on seasonal karst lakes known as turloughs. There are over 400 recorded turloughs across Ireland, the majority of which located on limestone lowlands. Turloughs can completely dry during summer months but extend to hundreds of hectares during the winter flood season. The practical limitations of establishing and maintaining a network of over 400 turloughs supported the use of remote sensing and GIS techniques to delineate flood extents and monitor flood prone areas in near real time using passive satellite imagery such as that of the ESA Copernicus programme. Measurements at 50 sites for over 18 months were used to calibrate and validate results from satellite data. With limited recorded groundwater flood data, the use of remote sensing data provides historical archives of images to look at past flood conditions to optimise the detection of groundwater and delineate maximum groundwater flood maps. These new data will improve the fundamental hydrological understanding of groundwater flooding in Ireland, enabling key stakeholders to develop appropriate flood mitigation measures and allow for informed flood assessments to be made in future.

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Session Classification : Parallel

Track Classification : Topic 5 - Tools, methods and models to study groundwater
Mapping groundwater dynamics in the Netherlands: three dimensional insight in groundwater systems based on the Dutch national database of subsurface information (DINOloket.nl)

Thursday, 26 September 2019 17:15 (15)

The Geological Survey of the Netherlands (TNO-GSN) maintains a public national database of groundwater head observations (http://www.dinoloket.nl). These measurements contain valuable information about the groundwater systems. All groundwater head time series have been simulated using transfer-noise modelling with precipitation and evaporation as explanatory variables. The impulse response function (IRF) for precipitation has been used as a system signature. The individual time series models are available online with interactive graphics (https://www.grondwatertools.nl/grondwatertools-viewer).

The total response (area underneath the IRF) and the average response time have been mapped for the major aquifers. Thereby, the lateral consistency has been checked. Also, the vertical consistency has been checked for multi-piezometer wells. The application of model evaluation criteria and the consistency checks on the modelled precipitation IRFs allowed us to select piezometers with reliable time series models.

This selection offers a far more homogeneous dataset of piezometric head informations than the original measurements. This means it can provide more reliable insight into the groundwater systems. We used the selection to create maps showing various aspects:

1. Response time of precipitation response
2. Yearly fluctuation - regime curve
3. Long term trends

The average response time in the precipitation IRF is a major characteristic of the groundwater system providing insight in the boundary conditions and hydrogeological situation. Also, the response time is important for monitoring and management activities.

The yearly fluctuation of the groundwater head has practical implications for land use and utilization of the subsurface. This fluctuation can be visualized for a piezometer using the regime curve, showing the average fluctuation over the year. Stochastic simulations using the time series models provide reliability bands around the regime curve, so that it can be put into perspective together with the deviations that may be expected. The yearly fluctuation has been mapped per major aquifer.

The long term trends due to anthropogenic influences are a major input for water (resources) management. The reliable time series models separate the influence of precipitation and evaporation from the other influences on the groundwater heads. The latter show up in the unexplained part (residuals) of the models. We assumed these are mostly anthropogenic influences. We applied a trend analysis to the residuals and mapped the resulting trends per major aquifer to show the occurrence of trends in the groundwater systems in three dimensions.

Based on head measurements from the Dutch national database with subsurface information, we provided insight in the groundwater dynamics of the Netherlands by means of maps covering various aspects. This is useful information for groundwater management and subsurface planning.
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Session Classification : Parallel

Track Classification : Topic 5.4 - Innovative approaches for understanding groundwater flow systems
Multi-method approaches to quantify groundwater and river exchange in lowland floodplains of Belgium

Monday, 23 September 2019 16:00 (60)

Floodplains play an important role in the hydrological cycle. They serve as buffer zones where water and solute exchange and heat transfer take place between the shallow groundwater (GW) and surface water (SW). Presented research focuses on quantifying the water flux between the shallow aquifer and river, which is often characterized by a high temporal and spatial variability.

A multi-method approach is used to measure the fluxes in three distinctive Belgian catchments (Zwarte Beek, Mombeek and Dijle). As GW head observations do not directly allow for quantifying the exchange flux, other state variable observations such as heat, hydrochemistry and isotopic tracers, are monitored to quantify the fluxes. Multiple temperature lances are installed in the catchments, which measure riverbed temperatures at multiple depths every 15 minutes. Point-in-time riverbed temperature measurements were carried out along the river channel to capture the spatial differences of the exchange flux. Based on these temperature data, the calculated fluxes have an order of magnitude varying from 10^-7 to 10^-6 m/s during observation period. The flux direction, representing either losing or gaining river, changes not only within the time of year but also along the longitudinal river profile. Besides the heat, a number of other tracers have been deployed, including major ion concentrations, electrical conductivity, stable isotopes (2H and 18O), and radon (222Rn). In total, 74 GW and river water samples have been collected during seasonal field campaigns. Major ion concentrations show that both river water and shallow GW belong to the calcium-dominated water type in all catchments. Nevertheless, the dominant anions vary from catchment to catchment and display a seasonal shift, e.g. from CaHCO3 type in summer/autumn to CaMIX type in winter in the Mombeek and Dijle catchments. Stable isotopic values of the autumn campaign show a narrow range: δ2H between −49.5‰ and -42.9‰ and δ18O between −7.4‰ and -6.4‰. Nearly all samples are isotopically depleted since they fall below the global and local meteoric water lines, suggesting a meteoric origin and evaporation effect for both GW and SW. Radon surveys indicate that its activities, especially in shallow GW, show large seasonal variations (from autumn to winter) in the Dijle catchment. A couple of SW samples from all three catchments show elevated radon activities which is most likely the result of GW exfiltration into the river. A quantitative analysis of these field approaches and preliminary interpretations will be presented and discussed during the conference.

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Session Classification : Poster with refreshments

Track Classification : Topic 5.3 - Advanced modelling tools for subsurface hydrology: from the vadose zone to deep environments
Dating groundwater with sulfur hexafluoride (SF6) using a simple, rapid sampling method

Tuesday, 24 September 2019 16:00 (60)

The average concentration of SF6 in the atmosphere of the Northern Hemisphere has been rising since the 1970s. By comparing the SF6 concentration of groundwater and the historical record of atmospheric concentration, groundwater can be dated from about the 1970s to the present. We therefore need to collect samples using an SF6-free pump or similar device, which prevents contact of the sample with the atmosphere, thus ensuring that atmospheric SF6 does not mix with the sample. Reduction of both the time and effort for water sampling caused by this constraint will result in more efficient investigation.

We have proposed a simple manually operated water sampling method using a well water sampler (well bailer bucket) for SF6-based dating of groundwater. During the process of groundwater sampling using a well bailer bucket, the sample comes into contact with the atmosphere. The calculation of SF6 transfer from gas to liquid phase indicates that during this process, the theoretical increase in the SF6 concentration of groundwater is less than 1%, which corresponds to a residence time of 0.2 years and is within the range of analysis accuracy of 3%.

This simplified method using a well bailer bucket (the simple method) can obtain the same results as the ordinarily used sampling method (the conventional method) in which water samples are collected without contact with the atmosphere. The difference between the SF6 concentration of the conventional method and that of the simple method is about 2% of the average value of both, which corresponds to about 0.5 years of apparent residence time. Even if sampled water comes into contact with the atmosphere during the sampling process by using the simple method, the dissolution of atmospheric SF6 into the sampled water is extremely small. Depending on the sampling depth and survey equipment, the simple method can reduce the sampling time (for example, a reduction of 60 to 70%, including preparation for sampling). The simple method, which does not use a pump, has no sampling depth restriction due to the pump head. Furthermore, the simple method can lessen the weight of equipment, reducing the burden on survey participants.
Management of groundwater-energy-food nexus for sustainability

Monday, 23 September 2019 12:00 (15)

Groundwater management is important for global and local sustainability, which is shown as large groundwater footprints through the global agricultural trade and local environmental problems due to groundwater depletion, as well as climate change impacts on groundwater resources directly and indirectly, and carbon emissions through human activities using groundwater. Groundwater, energy and food are interlinked each other beyond the boundaries of each shed as well as trans-spatially, such as local, national, and global, through the food and energy trades. Interactions between groundwater-food-energy nexus and environmental/economical/social impacts under the conditions of climate change and urbanization, are analyzed for global and local sustainability, in terms of multi-scale integrated management and governance of the nexus by increasing synergies and reducing trade-offs. Environmental changes and degradations such as air and water pollutions, land subsidence, and others, had been occurred significantly during the Anthropocene, as tradeoff of the economic development, even though the national and local government policies had tried to make synergy of groundwater-energy-food nexus.

To understand the relationships between social/economic developments and environmental change, some analyses have been made with the indices including self-sufficiency as a part of securities, water footprints for food production as nexus interlinkage and others, depending on the different spatial scale as transboundary of inter- and intra-connected nexus. Three databases are made with resources, interlinkage, and scenario in multi-spatial scale including Kyoto city, Kyoto prefecture, Kansai area, and Japan. A nexus model to analyze the change of the nexus structure has been developed, and assessments of the changes in three resources, carbon emission, environmental and economic impacts, are analyzed. Preference of local food production causes the decrease in energy consumption for food transports and carbon emission, on the other hand the increase in water and energy consumption in local area. Tradeoffs were found between economy and environment as well as local and national scale.

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Session Classification : Parallel

Track Classification : Topic 3 - Groundwater sustainability and governance
The environmental geochemistry behavior mechanism of Fe-Mn nodule in a oil contaminated site

Thursday, 26 September 2019 17:30 (15)

This study intends to use a petroleum contaminated site with Fe-Mn nodules in Henan oil field as a study area, study on the environmental geochemical evolutionary mechanism of the Fe-Mn nodule as electron acceptor, take the spatial analysis, adsorption/desorption experiments, column simulation test system, microbial identification and testing methods, reveal the mechanism of heavy metal ions leaching from Fe-Mn nodules and petroleum pollutants degradation, clarify the transition and transform rule in the interaction process, evaluate the control function and contribution rate of microorganism in the process.

We carried out microcosm experiments to examine the capacity of iron–manganese nodules to remove petroleum compounds at 15℃, which is close to the temperature of the aquifer. In the experiments about 81% of the crude oil disappeared, the nodules released at highest 90.14, 8.27, and 0.006 mg/L of Fe, Mn, and As, respectively, almost 16% of the iron–manganese nodules dissolved. Contrasted with the autoclaved controls, the microbial reduction of Fe and Mn and release significant amounts of As, Ba. The results indicate that iron–manganese nodules maintain rich, distinct bacterial communities under oil exposure that have the potential to remove petroleum compounds in anoxic conditions, while released Fe, Mn, As, etc, which has a potential hazard to groundwater.

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Session Classification : Parallel
Track Classification : Topic 8 - Groundwater quality and pollution processes
Development of the method predicting suitable area for installation of ground-source heat pump system using response surface methodology

Tuesday, 24 September 2019 15:00 (15)

Installation of Ground-Source Heat Pump (GSHP) system is gradually increasing in Japan. Thermal conductivity of the formation in Japan is smaller than that in continental area consisting of rock which is older than Quaternary because major cities and towns in Japan are located on Quaternary plains and basins. However, groundwater of Quaternary is actively flowing, and the heat exchange rate depends on the existence of groundwater and its flow rate. Therefore, GSHP suitability mapping has been carried out based on hydrological parameters such as groundwater flow velocity, groundwater temperature and hydraulic head in Japan. In this study, formularization of the relationship between heat exchange rate and its influential factor was conducted and the method to predict heat exchange rate from the results of groundwater flow and heat transport simulation using response surface methodology. First, a 3-D groundwater flow and heat transport model (regional model) using FEFLOW was constructed in the Sendai Plain, Japan. Horizontal model domain was extended up to the water divide of the plain; its area is about 3600 km². Vertical model domain covers from ground surface to the lower part of Neogene; the maximum model thickness is about 900 m. Calculated value of the simulation was verified based on field data of the groundwater levels and the subsurface temperature profiles. Next, identical ground heat exchanger models of dimensions 20 m × 20 m × 120 m were constructed at 33 locations to calculate heat exchange rates at these locations assuming a general closed-loop system based on the regional model. The operating scenario was set as 120 days of space heating per year from December to March assuming 24-h operation. The inlet temperature and flow rate of the circulation fluid were set as 5°C and 20 L/min, respectively. Heat exchange rate was calculated in the above condition and factors affecting the rate was examined by statistical methods. It was found that the main factors affecting heat exchange rate were groundwater flow velocity, subsurface temperature and thermal conductivity in the Sendai Plain. The equation using quadratic polynomial had better reproducibility of the amount of heat exchange than that using first-degree polynomial.

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Session Classification : Parallel
Track Classification: Topic 5.3 - Advanced modelling tools for subsurface hydrology: from the vadose zone to deep environments
Governance and Management of high arsenic Ground water based Drinking water supply in India

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Abstract
The high concentration of arsenic in ground water of the alluvial plains of Ganga Basin comprising the states of Uttar Pradesh, Bihar, Jharkhand and west Bengal as also in neighboring country, Bangladesh has emerged as a major drinking water issue, since ground water provides the main sources of drinking water in these areas. Significant researches are being carried out to understand the areal extent of contamination, causes of arsenic mobilization in ground water, impact of human health hazards, remedial interventions etc. The impact of excess arsenic in ground water (more than 10 ppb) has caused considerable concerns, both for drinking water and food chain. It has, therefore, become imperative to evolve a policy framework to address such arsenic menace so that sustainable remedial measures can be developed and to provide relief by supplying safe water to the suffering millions. High arsenic in ground water has been detected in the state of West Bengal in India restricted mainly in the lower gangetic valley since 1983. The maximum number of arsenic affected population due to ingestion of contaminated groundwater has been reported from the state. A concerted and well conceived plan to mitigate the arsenic menace is being practiced here by the Government of West Bengal who is primarily responsible for safe drinking water supply in the rural areas. Arsenic Task Force for the state of West Bengal has been set up in the year 1994 whose task is to plan and overview the progress and monitoring of the mitigation measures being under taken. Apart from short term mitigation measures, long term solutions to provide sustainable drinking water supply to the arsenic affected areas have been executed which have been discussed in the paper. In addition to utilization of treated surface water sources a number of treatment techniques of contaminated ground water are in use for dearsenification of water. Awareness generation and behavior change communication are proving to be quite useful. People’s participation in execution and maintenance of the community drinking water supply projects are being encouraged. Other Arsenic affected states in India are also taking suitable measures based on their research findings and successful implementation of projects in west Bengal. Government of India is also taking keen interest in coordinating the efforts among the various arsenic affected states.

Keywords: Arsenic Mitigation, Technological options, Sustainable mitigation measures, Behavior Change.
Track Classification:  Topic 3.1 - Groundwater and water security in developing countries
Terminal Lake levels fluctuate in time as a result of climate change and/or anthropogenic reasons. This phenomenon has recently occurred in some lakes around the world (e.g. Aral Sea in Uzbekistan, Lake Urmia in Iran, Chad Lake in Africa, Mono Lake in California, etc.), which serve as a discharge base of groundwater basins.

In this study, the effects of extreme fluctuations of the Dead Sea and Lake Lisan Levels on the flow field of the Eastern Mountain Aquifer (EMA) were examined by a numerical hydrogeological model and found to be significant. The model was first calibrated to the current condition and then simulated the paleo and future groundwater-flow-field within the EMA. The results show that currently, 90% of the EMA water discharges in springs located at the Dead Sea shore, at an elevation of ~-430 m below sea level (mbsl), with almost no discharge north of the Dead Sea. However, when Lake Lisan stretched over a larger area within the Jordan Valley, at elevations of -160 to -250 mbsl, as much as 35% of the EMA water discharged through paleo-springs at the central Jordan Valley, north of the Dead Sea.

The high levels of the Lake Lisan affected the groundwater flow pattern by two means: (1) The hydraulic gradient was different from the current one, thus the flow from the Samaria Mountains (north-west side of the basin) discharged in the close paleo-springs, in the central Jordan Valley; (2) The groundwater flow within deep sub-aquifers was blocked due to higher location of the fresh-saline waters interface. Furthermore, the modeling shows that as the Dead Sea level drops down to ~-550 m, as expected to occur in the next centuries, the current coastal springs will dry up and the groundwater will migrate and discharge close to the Dead Sea along delta-fans.

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**Session Classification**: Parallel

**Track Classification**: Topic 5 - Tools, methods and models to study groundwater
Evidence for changes in groundwater drought in temperate environments associated with climate change

Monday, 23 September 2019 18:00 (15)

There is currently a significant gap in our understanding of the effect of anthropogenic warming on groundwater drought. This is due to a number of factors including the limited availability of long groundwater level time series suitable for analysis, the low signal-to-noise ratios characteristic of many hydrological systems, and the infrequent nature of episodes of groundwater drought in temperate systems. Formal attribution of groundwater droughts due to anthropogenic warming is also challenging because of the potentially confounding influences of land use change and groundwater abstraction on groundwater drought. In the present study, we have not attempted to formally attribute groundwater droughts to climate change. Instead, we investigate how known centennial-scale anthropogenic warming may be modifying the nature of groundwater droughts when other factors are discounted, and address the following question: how has the occurrence, duration, magnitude and intensity of groundwater drought, as expressed by changes in monthly Standardised Groundwater level Index (SGI) and in episodes of groundwater drought changed since 1891 under anthropogenic warming?

Standardised indices of monthly groundwater levels (SGI), precipitation (SPI) and temperature (STI) are analysed, using two long, continuous monthly groundwater level data sets from the UK, for the period 1891 to 2015. Precipitation deficits are the main control on groundwater drought formation and propagation. However, long-term changes in groundwater drought include increases in the frequency and intensity of individual groundwater drought months, and increases in the frequency, magnitude and intensity of episodes of groundwater drought, are shown to be associated with anthropogenic warming over the study period. These is a transition from coincidence of episodes of groundwater and precipitation droughts at the end of the 19th century, to an increasing coincidence groundwater droughts with both precipitation droughts and with hot periods in the early 21st century. In the absence of long-term changes in precipitation deficits, it is inferred that the changing nature of groundwater droughts is due to changes in evapotranspiration (ET) associated with anthropogenic warming. Given the extent of shallow groundwater globally, anthropogenic warming may widely effect changes to groundwater drought characteristics in temperate environments.

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Session Classification : Parallel
Track Classification : Topic 2 - Groundwater and climate change
Using groundwater heat data as additional state variable observation to decrease groundwater models uncertainties: an application to the Neogene aquifer, Belgium.

Heat is a naturally occurring widespread groundwater tracer that can be used to identify flow patterns in groundwater systems. Recent work has broadened the use of heat in a quantitative way by incorporating it in formal solutions of the inverse problem to estimate hydraulic properties and groundwater flux. This is commonly done with numerical codes that at least enable one-way coupling of the different processes, i.e. groundwater flow and heat-transport. Temperature measurements, being relatively inexpensive and effortless to gather, represent a valuable source of information which can be exploited in to support performance assessment studies. For the Neogene aquifer in Flanders, groundwater flow and solute transport models have been developed in the framework of safety and feasibility studies for the underlying Boom Clay Formation as potential host rock for geological disposal of radioactive waste. However, the simulated fluxes by these models are still subject to large uncertainties, as they are typically constrained by hydraulic heads only. While the evaluation of candidate host rocks continues, the use of heat as an additional state variable for inverse conditioning is being explored. Current methodological developments to integrate such additional observations will allow i) to test our current understanding and corresponding models of the system, and ii) to decrease the uncertainties associated with model outcomes by a joint inversion approach. In a previous campaign in 2015, temperature-depth (TD) profiles data were obtained at 20 selected sites across the Nete catchment. These will be further used as observations for the heat-transport modelling. Additional TD profile data is proposed to be collected in a future campaign to complement the existing dataset. Furthermore, temperature values were imposed for the top boundary condition retrieved from NASA’s MODIS (Moderate-resolution Imaging Spectroradiometer) land-surface temperature (LST) imagery remote sensing monthly data from 2001 to 2016. This approach seems suitable as the idea is to learn as much as possible from measurements from low to non-invasive techniques, particularly within the framework of disposal of radioactive waste. Here, we will present the first results and interpretations of the gathered TD data, and the improvements that the satellite data bring with respect to a previous, more ad-hoc approach. This is a first step in testing the use of heat as an additional state variable, for constraining groundwater flow and solute transport models at the catchment scale.

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**Session Classification**: Poster with refreshments

**Track Classification**: Topic 5.4 - Innovative approaches for understanding groundwater flow systems
New isotopic surveys on the Poiano karst system

Thursday, 26 September 2019 15:00 (15)

This research deals with the application of stable isotope analyses to evaluate the most recent Poiano karst spring hydrogeological model proposed by Chiesi et al., 2010. The Poiano karst system is made up of Triassic gypsum/anhydrite evaporites outcropping in the northern part of the Apennine chain (Italy), and is bounded by the Lucola, Secchia, Sologno and Ozola rivers. According to the current hydrogeological model, this aquifer is mainly fed by the Lucola River. The Sologno River and meteoric recharge are believed to be secondary sources. The initial results from 46 water stable isotope analyses (d18O, dD) sampled monthly between Aug-2017 and May-2018 from the Poiano Spring, 3 shallow springs, and 15 river gauges were used as natural tracers to define the recharge shares for the Poiano karst system.

The preliminary isotope results point out a new highlight with respect to the recognized hydrological model. The d18O-dD analysis shows a scarce isotopic affinity of the Poiano Spring with the Lucola River, a strong isotopic affinity of the Poiano Spring with the Secchia River, and a moderate isotopic affinity among the Sologno River, Ozola River and shallow springs (effective recharge). These results are not in line with the most recent hydrogeological model of the Poiano karst spring and they can use to define a new hydrogeological model. In particular, the isotopic analysis indicate that the Secchia River must be considered one of the main sources that contributes to the total discharge of the Poiano Spring.

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Session Classification : Parallel

Track Classification : Topic 7 - Karst Hydrogeology
World total agricultural use of either chemical or mineral fertilizers was 110 Mt nitrogen (N) in 2016, reaching 69 kg N/ha the use of fertilizers per hectare of cropland (arable land and permanent crops) (FAO, 2018). The excessive use of nitrogen-containing fertilizers and manures is one of the main sources for the nitrate contamination of groundwater. WHO (2011) and the EU Water Framework Directive (2000) establish groundwater as polluted when nitrate concentration is equal or above the guideline value of 50 mg/L. Machine learning algorithms (MLAs) have been increasingly used to predict nitrate concentration in groundwater since they can recognize patterns between them and different features, learning from data without an imposed physical model. For the induction of an MLA, one can use all available features or select a smaller subset of them, removing redundant or spurious features. Many approaches can be used to evaluate the importance of features, which are related to groundwater pollution caused by nitrates. Feature selection (FS) is a process that selects a subset of the original features, optimizing the feature space considering a given criterion. FS contributes to a better understanding of nitrate pollution of groundwater, focusing on the relevant data and improving MLA performance. Different approaches for FS exist such as wrappers and embedded methods. Wrapper-based algorithms select a subset of relevant features based on the performance of a given learning method when the feature space is either increased or reduced. Within wrapper methods, different types of sequential searches can be applied to feed the MLA (sequential backward selection (SBS), sequential forward selection (SFS), sequential forward floating selection (SFFS) and sequential backward floating selection (SBFS)) were evaluated. On the other hand, embedded algorithms perform variable selection using internal measures of performance during the training of the algorithm. Random forest (RF) for classification was used as the learning method, where a bootstrap routine was incorporated into the wrapper and embedded methods to evaluate the generalization of the prediction model. A database of 20 features composed of hydrogeological and hydrological features, driving forces (sectors of activities that may produce a series of pressures, either as point and non-point sources) and remotely sensed variables (Normalized Difference Vegetation Index—NDVI) was used. Nitrates concentrations of 110 wells were used as a target feature. The SFFS RF wrapper outperformed the rest of the methods (mean misclassification error = 0.12, Area Under the ROC Curve = 0.92), selecting only three features: industries and facilities rated according to their production capacity and total nitrogen emissions to water within a 3 km buffer, livestock farms rated by manure production within a 5 km buffer and, cumulated NDVI for the post-maximum month, being used as a proxy of vegetation productivity and crop yield.

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**Session Classification**: Parallel

**Track Classification**: Topic 8 - Groundwater quality and pollution processes
Food security and the socio-economic development in many arid and semi-arid regions in Africa cannot be envisaged without a stable and reliable water supply to support local agriculture. Rural communities in those areas often depend on shallow groundwater resources associated with ephemeral alluvial systems to maintain water supply throughout the year. However, the potential of these aquifers to support agricultural intensification is often ignored in mitigation efforts. Preservation and harvesting techniques to manage or even enhance the alluvial aquifer storage are used and documented in many areas of the world. But not all techniques are effective, and often infrastructures are built without the necessary understanding of the local geological conditions, resource availability and aquifer dynamics.

May Gobo catchment, in the Tigray highlands of Ethiopia, is used in this research as a case study to analyze both the potential of small alluvial aquifers and the impact of storage enhancements to improve the water availability. Specifically, the effectiveness of two sand dams built in 2013 was evaluated. Fieldwork was conducted within the May Gobo catchment and neighboring areas, and multidisciplinary data collected to assess the critical elements determining the dynamic behavior of the alluvial aquifer. Surface and subsurface geological mapping, petrophysical characterization and the analysis of the chemical processes affecting groundwater were used to build a detailed hydrological model, which defined the characteristics of the aquifer units and their interconnections. Using climate data, the model was used to estimate aquifer recharge and the main recharge mechanisms. Finally, a numerical 3D model was constructed to better understand the groundwater flow and assess the role of the sand dams.

The groundwater model synthesizing all the data and insights gathered in the field has allowed simulations of the dynamic communication between the aquifer units and suggests that the role of the sand dam in the recharge of the river banks is rather limited. However, taken together, the results indicate that there is more potential for water storage in the sand river that is currently being used. Moreover, a substantial part of the storage built with the sand dams is lost through evaporation.

Implementation of the recommendations concerning the use of the resources stored by the sand dam could lead ultimately to better management of local water supply and development of agriculture in this area that today is considered marginal. These conclusions can be extended to other areas with similar characteristics and water resource challenges. The construction of numerical models, integrating all the available knowledge, provides a management tool to test development alternatives for these resources before implementation. This kind of approach should be used by decision-makers to decide on the optimal location and type of infrastructures to support agricultural development through groundwater resources.

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Session Classification : Poster with refreshments
Track Classification : Topic 1 - Groundwater assessment and management
Reducing Groundwater Overexploitation and Energy Consumption within Irrigation Districts by Automating Canal Operation: A Case Study in Iran

Unreliable performance of surface water conveyance and distribution systems in irrigation districts located in semi-arid regions of Iran resulted in increasing dependence on groundwater resources. For instance, in Qazvin Irrigation District, the “scheme irrigation efficiency” (sub-dividing in “conveyance efficiency” and “field application efficiency”) has decreased annually about 1% from 1900 to 2016. Accordingly, efficiency had declined from 48% in 1990 to 30% in 2016. In such conditions, around 347 MCM have annually extracted from the aquifer an additional source alongside surface water resources to meet their water demands. However, pumping groundwater has been led to adverse impacts on the aquifer (e.g., lower water table), environmental consequences (e.g., CO2 emissions due to diesel or electro engines). In this study, the impacts of upgrading the main irrigation canals water distribution and delivery systems, by employing Centralized Model Predictive Control (CMPC), on reducing the water pumping from the aquifers and consequently on reducing energy consumption, is investigated. To achieve this objective, an automated operational model employing the CMPC system is designed, calibrated and tested. Performance of the designed automated control system is compared to the current operating of the canal networks under the severe water shortages scenarios. According to the scenario, the canal inflow (i.e., the discharge releasing to the main canal) decreases by 20 percent while the water demands along the main canal are kept constant. The results reveal employing the centralized MPC system not only increased the cultivated area supplied by the surface water to 70%, but also the mentioned regions are fairly spread along the main canal from the upstream to the downstream parts. Thanks to the centralized inherent of the MPC, the water delivery practices are also improved from an equality perspective. In the next step, the spatial distribution of the adequacy of water distribution alongside the main canal is projected, to demonstrate consequences of enhancing the surface water distribution systems on the aquifer’s water extraction. The results show that about 28.3% groundwater overexploitation reduction over the study region. This amount of reduction in the groundwater extraction leads to 21.3% energy saving due to shutting off pumping of the currently deep and semi-deep tube-wells. The proposed framework of this study can be used for the assessment of the impacts of irrigation network operation on aquifers restoration and energy consumptions.

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Session Classification : Parallel

Track Classification : Topic 3 - Groundwater sustainability and governance
In the Guadalquivir Depression, the foreland basin of the Betic Cordillera, there are large masses of Triassic lutites with evaporites that were emplaced, as an olistostrome, in the old Miocene sea. These materials, which from the hydrogeological point of view behave as an aquitard, contain brine groundwaters that upwell in numerous springs and seepages, usually of very low discharge. These waters have traditionally been used for the production of salt in small artisanal salt pans. Measurements carried out in situ and chemical analysis of waters show that total dissolved solids values in water are between 100 and 300 g/L. The predominant ions are Cl\(^-\) (up to 182 g/L) and Na\(^+\) (up to 116 g/L) and significant contents of SO\(_4\)\(^2-\) (up to 11 g/L) and Ca\(^2+\) (up to 1.9 g/L) are also observed. These values are, respectively, close to saturation in halite and gypsum. Contents in Mg\(^2+\) (up to 1.3 g/L) and K\(^+\) (up to 0.9 g/L) are considerably lower and close to or lower than those of seawater.

The observed hydrochemical variability can be related to different mixing percentages of an ancient brine, possibly originated from marine waters, and meteoric waters of recent infiltration. Seawaters could come from the Miocene basin in which the olistostroma was emplaced and they would have dissolved gypsum and halite from the Triassic evaporites until saturation. After the emersion of the basin, the progressive erosive dismantling of the lutites with evaporites and the limited infiltration of meteoric waters would favor the release of the brine and its mixture with less saline waters.

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**Session Classification**: Poster with refreshments

**Track Classification**: Topic 8 - Groundwater quality and pollution processes
Origin and occurrence of the hydroxide water

Thursday, 26 September 2019 16:00 (60)

Usually the main anions in water bodies are bicarbonate, sulfate and chloride that form the corresponding hydrochemical facies. In Russia the name of the water facies is given in case when the proportion of the corresponding anion exceeds 20-25% of the total equivalent mass. Ions with such relative concentrations is called the main. Today we can confidently talk about the inclusion in the number of main anions hydroxide, nitrate, fluoride. Among them hydroxide water is quite a rare hydrochemical phenomenon.

Hydroxide water is a specific type of anionic water composition that is found in natural and technogenic water bodies. Its occurrence has a local character in springs or aquifers. It is characterized by a strongly alkaline reaction with a pH of more than 11.

Hydroxide waters are formed in water bodies as a result of dissolution of hydroxides minerals, hydrolysis of aluminosilicates in arid conditions, hydration of oxides, hydrolysis of carbonate salts, and dissociation of water molecules. In the majority of cases hydroxide waters are non-carbonate and usually are not linked to the carbonate system.

A case of dissolution of hydroxide minerals is described in Jordan. Here Maqarin springs are known coming out of sedimentary rocks and containing portlandite Ca(OH)2. Its dissolving causes a formation of hyperalkaline hydroxide calcium water. In the Northern Oman chloride-hydroxides springs originated from the hydrolytic decomposition of ultrabasic rocks of the Semile ophiolite belt were studied. A formation of hydroxide water is also known in technogenic condition arising from the combustion of lignite, brown and bituminous coal with high calcium content in ash. Its hydration leads to the formation of hydroxide calcium water. Hydrolysis of carbonate salts forms hyperalkaline water bodies where hydroxide ions met with carbonates.

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Session Classification : Poster with refreshments
Track Classification : Topic 8 - Groundwater quality and pollution processes
Unsaturated zone can play an important role in karst hydrology. Investigating its structure and hydrodynamic functioning is a very challenging task, but it is also a key to better assess and manage groundwater resources.

Classically, hydrogeological studies combine hydrodynamic and hydrochemical measurements. Flows in unsaturated zone are accessed through boreholes or within natural or artificial tunnels. In this work, we highlight representativity issues of flow dynamics derived from boreholes monitoring in karst unsaturated zone. We show that combination of borehole observations with non-invasive hydrogeophysical monitoring is required to assess hydrodynamic and structural properties at site scale.

Our study is implemented in the LSBB (Low Noise Underground Laboratory, France), an artificial tunnel of 3.8km dugged within the karst unsaturated zone of the fontaine de Vaucluse aquifer. We combined hydrogeological, hydrochemical and isotopic measurements performed at an outflow within the tunnel with hydrogeophysical surface-based measurements, hydrodynamic monitoring and logging of three boreholes at the surface above the tunnel.

Results show that: a) boreholes located in similar geophysical context with small in-between distance (18m) may exhibit very different hydrodynamic behaviour, which questions the spatial representativity of the flows derived from boreholes monitoring; b) while artificial tunnel and boreholes provide access to karst unsaturated zone, their implementation may disturb natural flow pathways and thus hydrodynamics of the medium; c) combination of classical hydrogeological measurements with surface- and borehole-based geophysical measurements can provide relevant insights in flow dynamics, but implementation of hydrogeophysical measurements is time-consuming, and remains constrained by field conditions.

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Session Classification: Parallel

Track Classification: Topic 5.1 - Dynamic Analogues
Groundwater resilience in urban water cycles: Experiences from the South

Tuesday, 24 September 2019 16:00 (60)

Cities in the Southern African region face unplanned urban growth outpacing social, economic, and institutional interventions, hence providing many challenges to water professionals and decision-makers for a sustained water security. Recent drought experiences of the City of Cape Town, South Africa, has brought groundwater and its potential role in ensuring resilience to recurring droughts and general water insecurity to the forefront. The role of groundwater in resilience, however, is poorly integrated in the urban areas of the South with mixed messages about groundwater storage, contemporary rates of resource renewability and the wider impacts of uncontrolled aquifer depletion and pollution.

A systems perspective on groundwater resilience within the context of urban water cycles is taken using the 2014 OECD Guidelines for Resilience System Analysis as an analytical framework. This allows better understanding of the complexity of groundwater to support urban living and the impact of urbanism on natural groundwater systems. The paper reflects on the groundwater challenges (i.e. rising and declining groundwater levels, groundwater quality deterioration and saline intrusion) facing major urban areas of Southern Africa: Cape Town, Dar es Salaam, Johannesburg-Pretoria and Lusaka. The paper concludes with lessons for groundwater resilience learned from the recent drought in the City of Cape Town.

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Session Classification : Poster with refreshments

Track Classification : Topic 10 - Urban groundwater
Assessing the groundwater dynamics, recharge and storage potential in the Limpopo river sand deposits

Tuesday, 24 September 2019 16:00 (60)

Chokwé and Guija, two districts of the Gaza province, in Mozambique, are located at the downstream part of the Limpopo river basin. The latter is a shared basin between four countries in which the development of water infrastructures upstream has a high impact on the water quality and availability downstream. Furthermore, neither the quantity nor the quality of the Limpopo River’s water that is entering the territory of Mozambique is properly monitored. Moreover, the Limpopo River has been characterized to be no longer perennial which makes the farming conditions more difficult. In fact, the average annual rainfall and evapotranspiration are respectively of 610 and 1649 mm in the province of Chokwé and the irrigation scheme is able to cover the water demand of about 20%.

The need for an alternative water resource is necessary in order to support the existing system. It is in that perspective that this research is studying the use of sand rivers as a potential water resource to support particularly the small-scale farmers. For that to be done, several field measurement and laboratory analysis have been carried out, such as geophysical survey, groundwater level measurements, hydraulic conductivity measurement, water chemistry and stable isotopes analysis, sediment and porosity analysis.

The study shows that the annual flood event of the Limpopo River is the main process that recharges the sand river aquifer. However, the majority the flood’s water is not stored in the sand river system but it refills the sand river aquifer to its initial groundwater level, which will be followed by progressive losses up to the next flood event. The geophysics revealed a total depth of around 15 meters in Guija and 10 meters in Chokwe, in which 10 (±1) m and 6 (±1) m are saturated by the dry period. In addition to that, the effective porosity is around 20% which can store a lot of water given that the sand river in both sites is underplayed by a clayey formation. The field measurements indicate that the groundwater from the sand river is discharging into the river in the dry period. The groundwater has low salinity and sodium hazard compared to the river’s water, which makes it more suitable for irrigation purposes. The main processes that affect the water quality are evaporation, degassing, dissolution and dilution. The dilution takes place only during the flood events while the other processes will continuously affect the water quality of the whole system. The study shows that the groundwater contained in the sand river tends to have similar characteristics as the rainwater, and its characteristics remain the same at the end of the dry period.

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Session Classification : Poster with refreshments

Track Classification : Topic 1 - Groundwater assessment and management
Climate change and Australian groundwater

The predictions of climate change in Australia are for a continuation of current trends, namely an increase in temperature (high confidence), an increase in extreme rainfall intensity (medium confidence), and a reduction of rainfall and runoff, with increased drought periods in southern Australia (medium confidence). Given the high climate variability in Australia and the winter-dominance of runoff and recharge in southern Australia, these climate trends will have a major impact on water resources in southern and eastern Australia. Groundwater is a major component of drought contingency measures for most areas. Far south-western Australia is already experiencing declining surface and groundwater resources, as a result of climate shifts, and are developing alternative sources of water. Such an obvious trend is expected to be masked for other southern areas by climate variability and only becoming evident during extended drought periods. This talk discusses the current knowledge with respect to risk assessment and management of climate change impacts on Australian groundwater.

Any reduction of rainfall is likely to mean amplified reductions in diffuse groundwater recharge. This would imply a reduction in extraction limits and the ability of groundwater to be used in droughts in southern Australia. However, the salinity of many groundwater systems means that most groundwater is not suitable for irrigation and systems are not stressed. Rather than a broad area of groundwater systems in southern Australia being vulnerable to climate change, the spatial pattern of vulnerable systems is more variable. This allows vulnerable systems to be treated in more detail, accounting appropriately for changed water demand, changes in surface water, availability of alternative sources, maintenance of water supply to groundwater-dependent ecosystems, changes in recharge due to changing land use, and changes in localized recharge (mainly from floods and river regulation). The challenges in predicting future impacts on groundwater are the uncertainties in climate forecasts, hydrogeological properties and inputs and irrigator behavior and demand.

Adaptive management used for stressed groundwater systems currently include water level response management, groundwater trading, groundwater triggers for localized areas and carry-over rules. There has been variable success in the application of these adaptive measures due to the lack of response once thresholds are triggered, the immaturity of groundwater trade and compliance and metering issues. However, by international standards, groundwater systems are managed sustainably and there will be pressure to resolve such issues.

Alternative sources of water, should they be required, often involve groundwater. Examples include deeper groundwater systems, managed aquifer recharge, desalination, demand management and changing recharge through changed land use. The severe conditions and increasing demand in the Perth region of south-western Australia means that water planning for climate change is most advanced there.

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Session Classification: Parallel

Track Classification: Topic 2 - Groundwater and climate change
A regional-scale assessment of soil moisture changes in Golmud River Basin, China

Monday, 23 September 2019 16:00 (60)

A regional approach was presented in this paper for the spatiotemporally distributed assessment of soil moisture changes in an arid area where ecosystems are highly groundwater dependent. To achieve this, the recent trends (from year 2002 to 2016) of soil moisture in Golmud River Basin were assessed using a combination of remote sensing and CLDAS data.

The Golmud River Basin is located in middle part of southern Qaidam Basin which covers a surface area about 4,566 km². With average elevation of 2780 m above sea level, the area is a plateau basin and has a typical arid climate. The annual precipitation is only 40 mm and most precipitation is concentrated in summer season from June to August. The annual air temperature is 4.7℃ and the winters are cold and windy. The pattern of land cover is as follows: 7% water bodies (mainly salt ponds), 12% shrub and grassland, 1% farmlands, 80% desert and salty areas.

MOD09A1 data of summer (June to September) from 2002 to 2016 formed the core datasets and the Apparent Thermal Inertia (ATI) was employed as the main method for mapping spatial distribution of soil moisture in Golmud River Basin. The Mann-Kendall non-parametric test was used to discuss the time series trends of soil moisture in this research.

The results revealed that the highest ATI is observed in the salt pond areas and it can reach up more than 0.08. Higher ATI areas are mainly occurred in farmlands, followed by grasslands and shrubs. On the other hand, the small ATI areas are mostly clustered in desert areas and ATI can be reduced to 0.02. When we look at the time series change of the annual ATI in the Gulmud River Basin, it generally increases during the period of 2002-2016 and the annual average ATI is varied between 0.02 and 0.03. According to the spatial distribution of the trends, the ATI of most areas has increasing trend and the decreasing trend is only happened in small parts of salty areas in the middle-east river basin. The ATI estimated from remote sensing data are in good agreement with the corresponding CLDAS soil moisture data in all four layers (0-10 cm, 10-40 cm, 40-100 cm, 100-200 cm) and the R-squares between their correlations are 0.80, 0.85, 0.84, 0.76, respectively. The soil moisture is increased with the depth to land surface and the value of layer 0-10 cm is obviously smaller than that of the other three layers. The vegetation cover is an important impact factor for soil moisture and the climate has no big effect on soil moisture due to the small precipitation in the Golmud River Basin.

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Session Classification : Poster with refreshments

Track Classification : Topic 2 - Groundwater and climate change
NUMERICAL STUDY ON SPRING WATER IN NON-UNIFORM SLOPES AT HEAVY RAIN

Tuesday, 24 September 2019 16:00 (60)

Spring water that appears on the slope during heavy rain is widely known as one of the signs of slope failure. The appearance of spring water means that the groundwater level has risen to near the ground surface. In addition, soil runoff and slope erosion associated with spring water may lead to a decrease in slope strength. Therefore, spring water is one of the important factors in considering the seepage flow in the slope during heavy rain. However, in the conventional seepage flow analysis assuming uniform field, the situation of the locally appeared spring water cannot be expressed due to the spatial heterogeneity of the hydraulic conductivity. In this study, the relationship between rainfalls, permeability of slope, thickness of surface layer, and the amount of spring water was examined quantitatively by using the stochastic fractal model as a spatial distribution model of hydraulic conductivity and three-dimensional numerical seepage flow simulation. As a result, it was shown that the amount of spring water was clearly underestimated by assuming the slope to be uniform. In addition, it was shown that when the permeability of the slope is relatively low, the groundwater level tends to rise for the same amount of rainfall, so springing is likely to occur. On the other hand, when the thickness of the slope is thin and the amount of rainfall is high, the amount of spring water was larger on the higher permeability slope.

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Session Classification: Poster with refreshments
Track Classification: Topic 5 - Tools, methods and models to study groundwater
A study on the performance of a groundwater heat pump with doublet system

Monday, 23 September 2019 16:00 (60)

Groundwater heat pump (GWHP) with doublet can be used as a highly efficient heat exchanger for air-conditioning according to the hydrogeology of installation site. As an open loop type geothermal heat pump a lot of systems have been installed over the world but it is hardly adapted in South Korea because of the lack of awareness, complex regulation and doubt in technology. We studied on the performance of the system in a pilot test building. In order to characterize the aquifer several tests were carried out in pumping and injection wells having the depth of 150 m. The measured hydraulic conductivities are ranged from $6.26 \times 10^{-5}$ cm/s to $1.65 \times 10^{-3}$ cm/s. The groundwater levels were monitored during one heating season with regard of geothermal heat pump operation which demands groundwater pumping, heat exchange and injection to the well. The performance of the system depends on the hydrogeology and the temperature of aquifer, and the installed mechanical equipment. The tested pumping and injection rate was 120 m$^3$/day and the groundwater level was increased around 0.5 m at injection well and the level at pumping well was lowered to 22 m below initial water level. The system performance of heating condition during one winter season was monitored. The interpreted performance data would be helpful to design economical GWHP and improve the technical feasibility.

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Session Classification : Poster with refreshments

Track Classification : Topic 1 - Groundwater assessment and management
Identification and Quantification of Spatial and Temporal Hyporheic Fluxes Using High-resolution Distributed Temperature Sensing in the First-order Alpine Stream in Taiwan

Hydrologic systems are strongly influenced by interacting processes that from pore space to watershed scale, but it remains a challenge to describe, model, and observe these processes at high resolution in the field. Recently, the Raman spectra distributed temperature sensing (DTS) for use in hydrologic application presents an opportunity for temperature measurements continuously in both space and time and provides a comprehensive picture of heterogeneity for the entire system. Chichiawan Watershed in Taiwan is the only habitat for the endangered species of Formosan land-locked salmon. However, the stream fragmentation, no surface streamflow, seriously reduced the salmon population, hampering the restoration work. Therefore, the utility of combining a high-resolution DTS with long-term monitoring data in the piezometers was to illustrate the complicated dynamics of hyporheic fluxes and to identify a suitable river restoration strategy to mitigate the effect of fragmentation on endangered salmon. The DTS measurements was conducted on the length of the 1,250 m reach covering the fragmented segment of creek from 7-13 November 2018 and seven installed piezometers provided the long-term water levels and streambed temperatures. The results showed that the propagation of stream fragmentation has been observed and the groundwater inflows has been clearly identified. The concentrated locations of groundwater inflows at the downstream confirmed the downstream channel is a perennial stream. The upwelling fluxes is differentiated from the regional groundwater and their contributed ratio vary with time and space. River restoration to mitigate the stream fragmentation can extend the habitat of salmon and the upwelling cold water can provide the thermal refuge for salmons during the summer.

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Session Classification : Parallel

Track Classification : Topic 5 - Tools, methods and models to study groundwater
Drivers of rainfall isotope composition in the northern Chilean Central Andes

Monday, 23 September 2019 16:00 (60)

The Central Andes is a geographical barrier that exceeds the elevation of 5000 m a.s.l. The Central Andes is constituted by two mountain ranges: the Eastern Cordillera and the Western Cordillera. Between them, the Central Andres plateau is well known for its fresh and salty lakes and its salt flats. During the austral summer, the strong easterly winds bring moisture from the Atlantic Ocean to the Central Andes. In the Eastern Cordillera (i.e. Bolivia) the strong continental and altitude effect component on the rainfall isotopic composition suggests the high influence of moisture sources from the Atlantic Ocean in the Eastern Cordillera during the austral summer.

The Pacific Ocean is considered a secondary and limited source of moisture to the Western Cordillera. During the austral winter, the Western Cordillera and the high plateau receives from the Pacific Ocean a precipitation less than 20% of annual precipitation. The limited rainfall isotope data and isotope mapping studies from northern Chilean translates into difficulties in the interpretation of changes in moisture sources. Despite this, we hypothesise that the northern Chilean Central Andes (latitudes 18° S to 24,6° S; elevation >3000 m a.s.l.) rainfall is enriched in heavy isotopes towards higher latitudes.

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Session Classification : Poster with refreshments

Track Classification : Topic 3 - Groundwater sustainability and governance
Water isotope monitoring to study transpiration and trees drought responses on Mediterranean karst

Karst environments are questioning because although they have dry, stony soils seemingly unfavorable to vegetation, they are often covered with forests. How trees can survive in environments that are hostile to vegetation is a key issue for scientists. This study uses xylem water isotopes and midday and predawn water potentials of branches to assess the origin of transpired water. The monitoring was carried out during the summers 2014 and 2015 in two contrasted Mediterranean forest ecosystems. The results show that the three monitored tree species (Abies alba Mill, Fagus sylvatica L and Quercus ilex L.) have developed adaptation strategies against water stress including a more intense exploitation of groundwater reserve in the karst unsaturated zone (vadoze zone) during the driest years. Quercus ilex, a species well adapted to water stress and growing in the driest site uses the groundwater resource very early in the summer season. Conversely, the two other species less submitted to drought, exploit groundwater resource only during severe drought. These results open up new perspectives to better understand eco-hydrological equilibrium and improve water balance modeling in karst forest settings.

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Session Classification : Parallel

Track Classification : Topic 7 - Karst Hydrogeology
Assessments of surface water-groundwater interactions in the arid zone — case study in the Yanqi basin, northwestern China

Monday, 23 September 2019 16:00 (60)

Groundwater is a critical water resource for human survival and social-economic development in arid and semi-arid areas. With the development of economy and the continuous increase of population, and especially to meet irrigation demands, aquifers are subject to intensive exploitation in the Yanqi Basin, in the central region of Xinjiang, China. The decreasing groundwater table changes the interactions between groundwater and surface water. To quantitatively evaluate the exchange capacity between river and groundwater, a flow model based on MODFLOW was built to simulate the interactions of river and groundwater in Yanqi Basin in a 10 years period. Results show that the water exchange capacity between surface water and groundwater increased obviously with the increasing groundwater exploitation. The exchange capacity increased from 1.18 hundred million m$^3$ in 2004 to 2.2 hundred million m$^3$ in 2013, when the groundwater exploitation increased from 1.19 to 3.8 hundred million m$^3$ in the same period. The groundwater exploitation was close to the value of available exploitation quantity in this area. The increasing river seepage due to excessive groundwater exploitation also plays an important role in the water level decline in the Kaidu River and in Bosten Lake. This implies the current utilization of groundwater resources in the Yanqi Basin is unsustainable and a strong groundwater resources management is needed in this extreme arid area.

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Session Classification : Poster with refreshments

Track Classification : Topic 1 - Groundwater assessment and management
Examination of the hydrologic cycle with long-term precipitation and groundwater level data

Monday, 23 September 2019 12:00 (15)

The impact of the ever-changing climate on Earth is already evident in the emergence of weather extremes and increased water demand from the agriculture. These changes and the human responses to it can greatly change many elements of the hydrological cycle. Weather extremes all appear in the amount and intensity of the fallen precipitation, while increased water demand in many areas has led to a permanent water level decrease in mainly shallow groundwater aquifers. Examining the changes requires large amounts of measured data, both for rainfall and water levels. In our study, these two elements of the hydrological cycle were analyzed in the Carpathian Basin involving several sample areas.

Changes in the amount and time distribution of the fallen precipitation were investigated across the entire Carpathian Basin by analyzing more than 100-year-long data sets, while the impact of the increased water demand was analyzed for the largest continuous agricultural area at the Hungarian Great Plain.

The different hydrological time series were analyzed by various mathematical methods. Spectral analysis based on the Discrete Fourier transformation was used to study long-term precipitation and shallow groundwater time series, and several deterministic cycles were calculated. In both rainfall and groundwater data, we have identified 13 cycles that were found in each time series, just like the 5-year, 12-year, and 4.5-year long cycles. With the help of Wavelet analysis, we also examined the extent to which these cycles changed during the 20th century, and whether there was an increase in the stochastic effects.

On long-term shallow groundwater time series, a complex method of factor and cluster analysis were performed based on the linear modeling of each monitoring point’s seasonality, so data sets were generated from the often incomplete time series registered in different measurement intervals, which will later meet the conditions of the spectral analysis.

The research was carried out within the GINOP-2.3.2-15-2016-00031 “Innovative solutions for sustainable groundwater resource management” project of the Faculty of Earth Science and Engineering of the University of Miskolc in the framework of the Széchenyi 2020 Plan, funded by the European Union, co-financed by the European Structural and Investment Funds.

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Session Classification : Parallel

Track Classification : Topic 2 - Groundwater and climate change
Validating the conceptual model of a fault-controlled geothermal resource through numerical simulations for a renewable and sustainable utilization

Thursday, 26 September 2019 17:30 (15)

The sustainable use of natural renewable resources represents one of the main tasks of the twenty-first century. The renewable geothermal resources can be profitably employed for energy production, heating and in several industrial processes allowing the reduction of the greenhouse gases and the human footprint. The knowledge of the main features that favor the development and the renewability of a geothermal system is the subject of detailed studies. In this context, numerical models reproducing the 3D geological setting of a geothermal system represent a tool to evaluate the involved geological and physical processes. The results can be used to perform site specific plans for a sustainable exploitation of the resource preserving it for the future generations. This procedure was adopted for the first time in the case study of the Euganean Geothermal System (EuGS; Veneto Region, NE Italy). Approximately 15 million cubic meters per year of thermal waters with a temperature ranging from 63 to 87 °C are exploited by approximately 200 wells. The Euganean thermal water is of meteoric origin and infiltrates an elevation of about 1500 m a.s.l., as suggested by its stable isotope composition. The recharge area is located on the Veneto Pre-Alps, approximately 100 km to the north of the exploitation area. The high-angle NE-dipping faults that characterize the central part of the Veneto Region allow the groundwater flow from the recharge area to the exploitation area. In the latter, a pattern of local fractures deforming the bedrock favor the rising of the thermal fluids toward the surface. The waters are mainly used for recreational purposes, producing an income of 300 million euros per year. To maintain this natural resource a detailed numerical model based on coupled simulation of fluid flow and heat transport was performed. Being the existence of this geothermal system related to a particular geological and structural setting, a 3D geological reconstruction was achieved by the use of MOVE software. The geological model was implemented into the numerical model through an unstructured mesh with the aim of maintaining a high geological detail. The results achieved by the numerical model allowed both to explain the geological processes that characterize the EuGS and to evaluated its renewability. The unravelling of these processes and of their interplay will allow to perform a management plan for the sustainable exploitation of the Euganean thermal water.
Session Classification: Parallel

Track Classification: Topic 5.4 - Innovative approaches for understanding groundwater flow systems
Nation-scale evaluation of required lengths for borehole heat exchangers considering advection effects of groundwater flow in Japan

Tuesday, 24 September 2019 16:00 (60)

Ground source heat pump systems are widely available as energy-saving systems for heating/cooling buildings, hot water supply, snow melting and other heat uses through heat exchanges between borehole heat exchangers and the underground of stable temperature. It has been long discussed that the size of borehole heat exchanger should be optimized in each condition of geology and hydrogeology. An advection effect in heat transfer by groundwater flow contributes to size reduction of borehole heat exchangers, when the groundwater flows with relatively high velocity, for example over several tens meters per year of Darcy velocity. This paper proposes a determination methodology of an optimized size for a ground heat exchanger considering groundwater flow in main watersheds basins for living in Japan. This study developed previous models of groundwater flow simulation in terms of high-resolution grid and hydraulic conductivity Furthermore, operation simulation of ground heat pump systems was performed to determine an optimal length of a borehole heat exchanger in two necessary temperature conditions and one performance condition. As a result, the oval average of calculated optimal lengths was 77.5m, and individual average in each basin increased in the northern direction depending on the heating loads. The size reduction by groundwater flow was 3.4m in average, and the reduction increased 9.1m when Darcy flow velocity was high (>20m/y). The negative correlation between Darcy flow velocities and optimal sizes was obvious and the correlation increased when the heating loads increased or when the ground thermal conductivities were small.

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Session Classification : Poster with refreshments

Track Classification : Topic 10 - Urban groundwater
The use of inflation in ensemble Kalman filter for the joint identification of contaminant source parameters and hydraulic conductivities in a sandbox experiment

Identifying contaminant source information from limited concentration measurements downstream from the source is a crucial step in groundwater pollution investigation for accountability and remediation purposes. However, in reality, the partially known but influential hydraulic conductivity field is always a significant obstacle in this inverse problem. In this work, we apply the restart normal-score Ensemble Kalman filter (NS-EnKF) method to identify the contaminant source and a non-Gaussian conductivity field jointly in a sandbox experiment by only using concentration measurements at a few observation points. As a preliminary step, we verify the restart NS-EnKF in a synthetic case mimicking the sandbox experiment. Some simple tries demonstrate that with a small ensemble size, measurement affected by observation errors and a complex sandbox conductivity lead to filter inbreeding. Consequently, a larger ensemble size, and several inflation methods are analyzed to solve this problem. We found that using a large ensemble size or Bauser’s inflation method avoids filter inbreeding. These conclusions are used to analyse the sandbox results to identify the contaminant source and the conductivities using the restart NS-EnKF. The results show that the restart NS-EnKF with a proper ensemble size or a suitable inflation method is capable to identify the contaminant source and the non-Gaussian conductivities in the sandbox experiment.

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Session Classification : Poster with refreshments

Track Classification : Topic 5.3 - Advanced modelling tools for subsurface hydrology: from the vadose zone to deep environments
Ibero-American Network for Shallow Geothermal Energy

Thursday, 26 September 2019 16:00 (60)

The shallow geothermal energy is experiencing a continued growth in Ibero-American countries in keeping with the worldwide concern about climate change, and of course, as a feasible option to reduce the economic charges of electricity uses.

To promote the use of alternative renewable energy sources in Latin America, such as shallow geothermal energy, the Ibero-American Program of Science and Technology for Development (Programa de Ciencia y Tecnología para el Desarrollo – CYTED) is financially supporting the Ibero-American Network for Shallow Geothermal Energy (Red Iberoamericana de Geotermia Somera – RIGS-CYTED). CYTED program has the aim to encourage the installation, development and integration of shallow geothermal energy systems for the development of productive activities, heating and air conditioning in buildings of different types in both urban and rural areas using mature technologies, tested and available in Latin America.

As an integrating network, RIGS-CYTED will create a cooperative working framework that facilitates and catalyzes the generation of new activities related to R+D+I around shallow geothermal energy in Ibero-America. This is possible because the participant groups are currently conducting scientific and technological activities related to shallow geothermal energy and other subsurface resources.

RIGS-CYTED is integrated by 11 research groups from 7 different countries (Argentina, Spain, Chile, Ecuador, Paraguay, Colombia and Mexico) enclosing a total of 55 researchers, with the collaboration of external partners from NGOs and SMEs. They all have committed during the next four years to join forces to achieve the proposed objectives.

The expected results from the first year of work will be related with the publication of a preliminary version for the Ibero-American Atlas of shallow geothermal potential. In the following years, RIGS members will evaluate existing and mature technologies, carry out a normative and regulatory analysis for each country, elaborate a good practice manual based on international specifications, identify applications at metropolitan scale with technical-economic feasibility analysis, identify the cluster of local companies related to the development and manufacture of equipment and components and, finally, develop numerical models to simulate the shallow geothermal exploitation in groundwater to assess environmental impacts.
Track Classification: Topic 9 - Groundwater and socio-economic development in Latin-America
Examination of the sensitivity of the different multi-criteria analysis methods in the mapping of the potentiality of aquifer formations in the Gar Djebilette region (extreme southwestern Algeria)

*Tuesday, 24 September 2019 16:00 (60)*

The aim of this work was to identify the potentially groundwater-producing areas of an environment characterized by a multilayer aquifer in the Gar Djebilette region, far southwest Algeria. Thus, Landsat 8 and Aster images were processed, merged, and interpreted to extract fractures from the study area. Drilling parameters were also used in this study. Their integration in two multi-criteria analyses made it possible to produce, on the one hand, the aquifer potentiality map according to the method of JOUDA et al (2006) and, on the other hand, the groundwater productivity map according to the Salay approach (2003).

Key words: multi-criteria analyses, groundwater productivity map, the aquifer potentiality map

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**Session Classification:** Poster with refreshments

**Track Classification:** Topic 5 - Tools, methods and models to study groundwater
A historical conflict around karst resources: the case of Tridaine spring (Rochefort, Belgium)

Thursday, 26 September 2019 15:45 (15)

The Tridaine spring was born in the XIX century when miners dewatered a Pb-Zn exploitation located in karstified Frasnian limestones. Its water was soon used for water supply. In the middle of XX century, both a quarry and a brewery installed their activities in the same region, one targeting stone, the other water. Both activities were gently coexisting until the end of 2006 when an extraction below the water table was intended by the quarry and solutions must be searched for replacing gravitational water supply, while preserving water quality. The concerned aquifer is included in a Geopark and it is under regulation due to the Water Framework Directive. Safe-guard zones have also been fixed for spring protection. Several detailed hydrogeological studies were achieved since then, aiming at conceptualizing the functioning of this “already no more natural” karst system, but nevertheless the efforts to reduce uncertainties could never guarantee the environmental/economic competition outcome until the present days. In this paper, we consider the value of data acquisition and objectivity for helping in the decision making and we underline the ubiquitous difficulty of prediction of impacts on the long term in karst systems.

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Session Classification : Parallel

Track Classification : Topic 7 - Karst Hydrogeology
A GIS-based water budget procedure used to evaluate groundwater resources under climate change scenarios

Tuesday, 24 September 2019 11:30 (15)

In the last years, water scarcity and drought severely affected southern Europe. Drought particularly afflicts Italy in different ways, mainly depending on the area hydrogeological setup and on the physical processes of precipitation-recharge interaction; the groundwater recharge decreases, due not only to rainfall reduction, but also to temperature increase. In southern Italy, the 1987-1993 period was probably the most critical, due to a long period of rainfall scarcity and historical minima of spring discharges. After this period, several drought years have been recorded (2002, 2007-2008, 2011 and 2017). The severity of these drought events has highlighted the need to evaluate the effects of possible future meteorological drought due to climate change on groundwater resource availability.

In this context, the Italian National Institute for Environmental Protection and Research (ISPRA) has developed the automatic “Nationwide GIS-based hydrological budget on a regular grid” procedure, named BIGBANG and currently at version 1.0, to evaluate the water budget components at monthly and annual temporal scale and in spatially distributed approach. This kind of approach also permits to analyze clipped parts (regions, hydrographic districts, river basins, etc.), to relate each other and to compare them to the whole territory as well. Moreover, the annual value of the water budget components can be evaluated by aggregating the monthly values or by calculating the water balance on yearly data. By using BIGBANG 1.0 procedure, the water budget comparison between a part and the whole territory provides a good agreement with local and more detailed analysis.

In the present study, the BIGBANG 1.0 procedure has been applied directly on a yearly basis as first approach to face the effects of possible future drought events associated to different climate change scenarios. BIGBANG evaluations are carried out, for Italy and for a region of southern Italy (Campania), at yearly scale and they are referred to four emission scenarios defined by IPCC in the Fifth Assessment Report and to short, medium e long time horizon.

Results suggest that, according to the RCP2.6 emission scenario, the reduction of groundwater recharge is quite constant for all time horizons for both Italy and for Campania region. On the other hand, the reduction of groundwater resources corresponding to the worst scenario in terms of GHG emissions (RCP8.5), is really critical, for Campania region and for Italy. Fortunately, there is still enough time to avoid severe situations, as predicted by the worst scenario, by means of the GHGs emissions reduction and of the sustainable management of the water resources.

This study could represent a “proof of concept” for the suitability of BIGBANG procedure, to simulate water balance under future climatic scenarios, to respond to the needs of decision makers, to plan water resources affected by climate change.

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A GIS-based water budget procedure for a coastal aquifer: Dr MARIANI, Stefano (Italian National Institute for Environmental Protection and Research (ISPRA))

**Presenter(s):** Prof. DUCCI, Daniela (Department of Civil, Architectural and Environmental Engineering, University of Naples Federico II)

**Session Classification:** Parallel

**Track Classification:** Topic 2 - Groundwater and climate change
Lowland coastal karst aquifers in the west of Ireland are considered to be highly vulnerable to pollution and impacted by multiple contamination sources on land (in particular, diffuse rural sources from agriculture and on-site domestic wastewater effluent) as well as by saltwater intrusion near the coast. Most of these aquifers are exceptionally complex which makes their protection and management extremely challenging. Human wastewater effluent from on-site wastewater treatment systems (DWTSs) is identified as a significant threat to groundwater quality in such lowland Irish karst environments, since approximately one-third of the population in Ireland is relying on these systems for the treatment of domestic wastewater. However, it is difficult to distinguish between agricultural pollution and DWTS effluent using only traditional water quality parameters or any single environmental tracing method. Hence, the impact of contaminants from DWTSs on groundwater quality must be assessed using a source-specific multiple-tracer approach. Such an approach allows the development and application of effective management strategies on the catchment scale.

Kinvara Bay catchment in the southern part of County Galway has been selected for this study due to a large number of DWTSs located above a well-developed shallow epikarst and extensively karstified Carboniferous limestone bedrock across the largest part of the catchment. The karst conduit network also receives significant quantity of relatively fast allogenic runoff from Devonian Old Red Sandstone bedrock hills in its eastern part. The catchment has been the subject of many studies over the years with respect to groundwater flooding, ecohydrology of turloughs and submarine groundwater discharge into the bay. Previous studies have estimated discharge and the nutrient loading from the two main springs into the Kinvara Bay using hydrological modelling; one of these springs being the outlet of a major karst conduit network (known to be the output of the allogenic recharge from the hills), while the other spring predominantly discharges water from more diffuse/autogenic sources.

Monthly hydrochemical and water quality parameter monitoring has been carried out over the course of a year, with concurrent application of microbial and chemical wastewater contaminant fingerprinting techniques. Such techniques include fluorescent whitening compounds, fluorescence-based investigations of organic matter with parallel factor (PARAFAC) analysis, specific anion ratio signatures, flow cytometry and faecal sterol and stanol profiles and ratios. The observed variations over time in concentrations of hydrochemical parameters and targeted contaminants specific to on-site wastewater sources at two springs were contrasted. The results, which have been compared to the known locations and densities of DWTSs in the area, have highlighted the previously suggested complexity of groundwater flow and distinctive conduit pathways within the same karst aquifer system. Such information can contribute to improved future catchment management policy to minimise the effect of contaminants on karst groundwater resources.

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**Session Classification**: Parallel

**Track Classification**: Topic 7 - Karst Hydrogeology
Contribution of Hydrochemistry and environnemental isotopes to the study of seawater intrusion in the coastal aquifer of the Eastern Mitidja Plain (Algeria)

Monday, 23 September 2019 16:00 (60)

The Mitidja Plain is situated in the north of Algeria, the Eastern part (575km²) lies by the sea in the north and is limited by the Atlas Mountains in the south. The region has two main aquifers separated in some places by the El-Harrach Formation (Calabrian). The Plaisancian marls (lower Pliocene) are the substratum of the whole area, the second and most important aquifer, Mitidja formation, is alluvial, coastal. The Eastern Mitidja plain constitutes a subterranean water reservoir essential for the agricultural, urban and industrial development of the capital Algiers. Recently, industrial activities, the spreading of exhaustive agricultural practices and the urbanization of the plain have lowered the quality of water. As many of the Mediterranean countries, Algeria has known a severe dryness during the last two decades. Unfavourable climatic conditions causing long period droughts have predictably led to a contamination of coastal groundwaters along the Mediterranean by ingressive seawater. Intensive pumping practices in use for the sake of securing water allocation for both populations and agriculture have drastically affected the groundwater reserves through overexploitation of the resource creating a consequent drawdown in the water table. During the dry season, the mobile fresh/sea water interface moves forward farther inland contaminating wells and boreholes. Two approaches making use of both hydrochemical and isotopic tools were applied to assess the extent of seawater intrusion. The Br vs. Cl plot showed that the points align in a parallel way to seawater dilution line confirming thus a marine origin for those elements. Na/Cl ratio vs. Cl plot brings to the fore two poles of points: one composed of shallow unaffected groundwater and a second one composed of deeper boreholes and wells in which seawater is present to different extents. This is further confirmed by isotopes which exhibited a wide range of values mirroring the affected and unaffected areas as well as those points submitted to intermingling between different endmembers.

Keywords: Seawater, Groundwater, Saline Intrusion, Environnemental isotopes, Hydrochemistry, Algeria.

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Session Classification: Poster with refreshments

Track Classification: Topic 1 - Groundwater assessment and management
Hydrogeological and geothermal sections of the Bükk Thermal Karst reservoir, Hungary

Thursday, 26 September 2019 16:00 (60)

The Bükk Mountains are situated in Northern Hungary. The Mountains are built up by karstified platform facies Triassic limestone formations interbedded by marl, clay and chert layers. Limestone units constitute a deep thermal karst water reservoir extending in the southern foreground of the Mountains covered by several thousand meters thick sediments. The research of Bükk thermal karst has been one of the main focuses of karst water researchers since decades. In the last fifteen years, the rate of water production has been constantly increasing for drinking water, balneological and also energetic purposes. Consequences of these the need for knowing even more accurate information about the thermal karst reservoir has increased also from scientific side. Target areas of present paper are the area of Eger-Egerszalók-Demjén and the surrounding of Miskolc. Maps and sections have been prepared representing situation of buried limestone surface in the 60’s, 90’s and millenium years. Since that time more thermal wells screening and exploiting thermal karst water have been implemented, extending available information of the thermal karst aquifers. In our research, the new exact geological data of drillings were used to create hydrogeological sections of the focus areas targeting more accurate visualization of thermal karst aquifers. Nowadays conducting geophysical tests during drilling process and in constructed well is also legal obligation. As a result very precise and accurate vertical geothermal log datasets of newly established production wells are available. Processing of geophysical thermal data and fitting them with the hydrogeological sections gives an opportunity for us to refine geothermal conditions of the areas.

Both the hydrogeological sections and the calculated geothermal gradient values in the point of the wells reveal to the extremely hectic situation of the buried Triassic limestone top confirming also previous research results and former sections of the areas. Evaluating all available information we came to the conclusion that no relevant and useful tomographic sectioning of the temperature conditions can be delivered. Instead of them we made the vertical isotherm maps to display temperature distribution conditions through the investigated section lines.

Acknowledgements
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Session Classification : Poster with refreshments

Track Classification : Topic 7 - Karst Hydrogeology
Identification of groundwater potential zones by using remote sensing, GIS and géostatistical analysis in Saida region, NW Algeria

Tuesday, 24 September 2019 16:00 (60)

One of the problems opposing the good management of groundwater resources, the efficiency of the implementation of boreholes and wells especially in karst aquifers where their exploitation is very difficult because of the complexity of underground hydrogeological transfers (which depend in particular on the nature of the rocks, the geological structure, the rainfall and the connectivity between faults).

In this case, the groundwater prospecting and productive drilling project requires the knowledge of a large number of geo-scientific, multidisciplinary, multisource and often multi format data. Among the best known techniques to achieve this goal is geophysical prospecting and experimental investigation. However, new approaches based on remote sensing and geographic information systems have been used more and more recently to replace geophysical exploration or field experiments that are very cumbersome and costly. These technical difficulties remain, until now, a major obstacle for the authorities concerned in choosing the most favorable impact points for groundwater exploitation.

The study area is Saida Mountains is part of the large Macta basin which extends to the northwest of Algeria, in the last tabular foothills of the southern flank of the Tellian Atlas, formed by the Tlemcen mountains, Daïa and Saida, on the threshold of the high steppe plains. Study Zone constitutes a vast structural plateau, where the main aquifers are mainly presented by the carbonate formations largely karstified of the Bajo-Bathonian and the surface formations of Callovo, Oxfordian and Plio-Quaternary.

Digital elevation model processing provided us the lineament map and the hydrographic network. Subsequently, the statistical analysis of these two elements allowed us to study the effect of the fracturing direction on the hierarchy of the hydrographic network and the surface flow direction. A relation was determined between the subsurface flow direction and the major fracture directions from the piezometric map analysis.

The geostatistical analysis of existing boreholes flow has allowed at the spatial scale the delimitation of high, medium and low estimated flow zones, the superposition of lineaments intersections has made it possible to determine the zones favorable for the implantation of the future drillings. The correlation between the validation map of suitable areas for the implantation of future drilling and actual drillings flow rates is approved.

Key Words: karstic aquifers, groundwater, drilling areas, RS, GIS, geostatistical analysis

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Session Classification : Poster with refreshments
Track Classification : Topic 5 - Tools, methods and models to study groundwater
A multi-method approach to quantify and simulate groundwater flow components in karst aquifers using pipe-network models

A multi-method approach to quantify and simulate groundwater flow components in karst aquifers using pipe-network models

Thursday, 26 September 2019 17:00 (15)

Karstified carbonate aquifers are highly heterogeneous systems characterised by multiple component porosities and permeabilities. The different porosities are associated with different permeabilities commonly interpreted as (fissured) matrix, fractures and conduits (Worthington, et al., 2000), generally associated with a turbulent quick-flow vs a laminar slow-flow component (Atkinson, 1977, Kiraly, et al., 1995).

Understanding, quantifying and numerically modelling these different flow dynamics is a challenge (Sauter, et al., 2006), yet, at the same time relevant for integrated water resources management.

This applied research comprises three autogenic limestone aquifers in the Republic of Ireland: a low-lying spring catchment dominated by diffuse recharge and influenced by surface water – groundwater interaction; an upland-lowland catchment dominated by quick recharge and flow; and a coastal aquifer discharging via submarine and intertidal springs into the Atlantic Ocean. Hydroclimatic parameters were monitored on an hourly time step, while groundwater catchments were delineated using artificial tracer tests, univariate and bivariate statistical methods, and signal analysis (continuous wavelet transform and wavelet coherence).

Based on the principle that individual flow components may resemble the drainage of linear reservoirs, a systematic approach was employed to separate continuous time series of a low-flow component (LFC) from spring and stream hydrographs, thereby representing drainage of the low permeability domain.

Using the results of the above mentioned methods, conceptual site models were synthesised and represented in a semi-distributed numerical environment in the form of a pipe-network model using InfoWorks ICM® (Innovyze software, Wallingford, version 7.0) (Gill, et al., 2013, Schuler, et al., 2018). This approach breaks down the aquifer into a combination of multiple quasi-linear reservoirs feeding into a network of pipes. Within the pipes, turbulent and open channel flow is modelled using the Saint-Venant equations of conservation of mass and momentum and the Colebrook-White equation, while laminar flow is solved applying Darcy’s empirical law.

The different models were calibrated against discharge, LFC time series and observed head in connected seasonally flooded lakes (turloughs) over at least one year. Validation ranged between six months and five years.

Overall, the model performances show that the conceptual site models can be very well solved numerically. Further, distinct recharge and flow components can be modelled using linear reservoirs, integrated towards the spring outlet within the pipe-network. This semi-distributed modelling approach is considered as a reasonable compromise in the framework of the heterogeneity of such karst systems, and hence, a promising tool for water resources management.

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A multi-method approach to quan...

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**Session Classification:** Parallel

**Track Classification:** Topic 7 - Karst Hydrogeology
Climate change impact on groundwater recharge in Slovenia in the period 2011-2100

Monday, 23 September 2019 17:45 (15)

Slovenia is a water rich country. More than 90% of its drinking water supply is covered from groundwater resources. Due to the geographical position of Slovenia on the junction of the Alps, Mediterranean, Dinaric Alps and Pannonian Basin, big inter- and intra-annual variations occur in both, time and space. For the determination of country-wide actual groundwater recharge quantities in high spatial resolution (100m grids), the water balance model mGROWA (Herrmann et al., 2014) has been implemented in Slovenia in 2017.

mGROWA is a deterministic water balance model, calculating runoff generation and runoff components including net groundwater recharge in daily time steps. On one hand mGROWA model results are used for water resources management issues. For this purpose runoff quantities determined in daily time-steps are aggregated to mean long-term averages, e.g. mean long-term groundwater recharge levels for hydrological periods or decades.

For assessing the impact of climate change on Slovenian groundwater resources the high temporal resolution of mGROWA is used in order to represent inner-annual shifts of groundwater recharge appropriately. Projections of groundwater recharge under climatic change conditions were analysed by running the mGROWA model with EUROCORDEX scenario data as climate input. For this purpose three scenarios were used: RCP2.6, RCP4.5 and RCP8.5. For each climatic scenario the combinations of regional and global climate models for Slovenia were selected based on the best fit of the climate scenario results to observed climate data in the past. For the RCP2.6 scenario two regional model combinations were used and for the RCP4.5 and RCP8.5 scenarios six regional model combinations. Arrived out for the

Model calculations have been carried out for the period 1980-2100 using the model period 1981-2010 set as the reference period. For assessing the the climate change impact, the periods 2011-2040, 2041-2070 and 2071-2100 have been selected. For these periods (and the 3 scenarios) geographical and geostatistical analysis were carried out, e.g. with regard to the absolute change and relative deviation of groundwater recharge for minimum, maximum and median. All that was analysed on annual and seasonal (spring, summer, autumn, winter) timescale along with a confidence analysis. The results indicate impacts of climate change on groundwater resources with distinctive periodical and regional patterns that will be presented at the IAH conference.

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Presenter(s) : Dr FRANTAR, Peter

Session Classification : Parallel

Track Classification : Topic 2 - Groundwater and climate change
Tracing bacterial transport in epikarst and karst-conduit aquifers with injected E. coli

Thursday, 26 September 2019 15:30 (15)

Because of limited filtration and rapid transport of groundwater and particulate matter, karst aquifers are susceptible to bacterial contamination. Water-quality standards are commonly tied to fecal indicator bacteria such as E. coli, but few studies have used E. coli as part of a suite of tracers to assess contaminant transport in karst environments. Conventional solute and particulate tracers, such as fluorescent dyes and microspheres, may not accurately represent processes that attenuate bacterial transport (e.g., sedimentation, straining, adhesion, and predation).

We used non-pathogenic E. coli isolates, together with rhodamine WT dye and 1-micron fluorescent latex microspheres, as tracers at three sites in Kentucky (USA). These included karst-conduit aquifers in Ordovician limestone of the Inner Bluegrass region (Blue Hole and Royal Spring basins) and epikarst in Lower Carboniferous limestone of the Mississippian Plateaus region (Crumps Cave site). In the Blue Hole basin, we injected wild-type E. coli labeled with the stable isotope nitrogen-15 into a swallet during a storm and monitored tracer arrival at the spring (~ 530 m downgradient) for 24 d. In the Royal Spring basin, we injected two E. coli isolates (kps [low attachment] and iha [high attachment]) into a sinkhole during baseflow conditions, and monitored tracer arrival at a well and the spring (~ 750 m and ~ 6.25 km downgradient, respectively) for 50 d. We injected kps and iha isolates at the top of epikarst above Crumps Cave during a storm and monitored tracer arrival at a cave waterfall ~ 30 m below for 109 d. E. coli were analyzed by isotope-ratio mass spectrometry for the Blue Hole trace and by quantitative polymerase chain reaction for the other traces.

Differences in the relative timing of tracer arrivals and peak concentrations at each site reflect differences in tracer characteristics and flow-path complexity. At Blue Hole spring, breakthrough of all tracers coincided, but E. coli exhibited more tailing than dye during the initial storm-flow recession, and only microspheres were remobilized by subsequent storms. In the Royal Spring basin, microspheres arrived at monitoring sites before E. coli, while dye arrived after the particulate tracers. Dye peaked prior to particulate tracers at the well but between microspheres and bacteria at the spring. In the epikarst trace, dye arrived at the waterfall prior to particulates, and its concentration peaked after kps but prior to microspheres and iha. In both the Royal Spring and Crumps Cave tests, all tracers were remobilized from storage during subsequent storms. We conclude that transport behaviors can vary not only between bacteria and abiotic tracers, but also between different E. coli isolates. Furthermore, tracer remobilization and recovery depend upon antecedent moisture conditions in the vadose zone and the extent to which flow occurs along multiple pathways.

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Session Classification : Parallel

Track Classification : Topic 7 - Karst Hydrogeology
Hydraulic tests are widely used for qualitative and quantitative characterization of aquifers. They allow understanding the conceptual model and estimating the parameters that govern the water flow by recording and interpreting the aquifer response to pumping/injection. This response needs to be represented in terms of drawdown, defined as the change in head caused by the pumping test. As such, they are calculated as the difference between the head that would have been observed without pumping (i.e., “natural” head) and the head that has been actually observed. The problem lies on how to evaluate the natural head. That is, heads monitored during a hydraulic test are usually affected by regional trends, recharge events and more generally, by perturbations other than those of the test itself. These perturbations need to be filtered from the time series to isolate the effect of pumping. Filtering is usually carried out by means of statistical methods (e.g. Fourier-based filtering, average removing method and adaptive detrending algorithm). Our work is motivated by long tests where the aquifer recent past may affect head evolution during the test. We propose a detrending methodology to be applied for hydrological series in complex systems, which consist on the development and application of two flow numerical models, jointly with the stochastic inversion, as a single tool for measured data filtering. We proceed iteratively between the two models, so that the most recent calibrated field is used for modeling natural head evolution and for calculating drawdowns. The method is illustrated by application to a synthetic and a real case.

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Session Classification : Parallel

Track Classification : Topic 5.3 - Advanced modelling tools for subsurface hydrology: from the vadose zone to deep environments
GROUNDWATER CHEMICAL AND ISOTOPIC CHARACTERIZATION OF AN AQUIFER IN BRAZILIAN CEARÁ STATE.

Monday, 23 September 2019 16:00 (60)

This work is being developed in the district of Pecém (Brazil) in a region included in the so called Polygon of Droughts, which presents a pluviometric regime marked by extreme irregularity of rains, in time and space. In this scenario, water constitutes a natural asset with a high limitation on the socioeconomic development of the region and even on the subsistence of the population. The objective of this work is to identify the quality of the groundwater, the salinization processes and the efficiency recharge of the aquifer, using isotope measurements of Oxygen-18 and Deuterium, physical and chemical analysis and measurements of concentration of the major ions, in a set of samples collected in 33 tubular wells, belonging to the Ceará Water Resources Management Company (COGERH) sampled in two collections. The pH measurements reveal acid waters with values of up to 6.0 and most of the hydrochemical data show waters chemically suitable for human consumption. The results of the electrical conductivity measurements show values lower than 800 μS/cm in 31 of the 33 wells sampled; the highest values were 826 and 1125 μS/cm, characteristic of waters with high salinity. The concentrations of the cations and anions of the largest elements present in the water, in the two collections, indicated waters of the sodium chlorite type in most of them. The average values of electrical conductivity in the first collection 434 μS/cm and in the second collection 260 μS/cm show dilution process in the groundwater caused by the recharge with rainwater also indicated by the pH values. The relations δ18O - δD evidence evaporation processes.

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Session Classification : Poster with refreshments

Track Classification : Topic 1 - Groundwater assessment and management
A superior indicator of microbial risk: real-time fluorescence spectroscopy

Thursday, 26 September 2019 16:00 (60)

The faecal contamination of drinking water is the biggest potable water quality issue on the planet. Contamination is inferred through the culturing of faecal-indicator bacteria (FIB), such as thermo-tolerant coliforms over at least 18h. We will demonstrate the use of fluorescence spectroscopy as a viable real-time alternative using data from over 550 potable water sources in India, Malawi, South Africa, and Zambia. Here, the technology is a significant indicator of the presence/absence and number of FIB in drinking water. We will then successfully demonstrate its application as an online indicator of E. coli in UK groundwater-derived public water supplies. Finally, we will discuss temporal relationships between fluorescence spectroscopy and FIB from the repeated sampling of 50 groundwater sources in Kenya and Uganda. These observations lead us to suggest that real-time fluorescence spectroscopy is actually a superior indicator of microbial risks at groundwater sources than the sporadic sampling and culturing of FIB.

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Session Classification : Poster with refreshments
Track Classification : Topic 8 - Groundwater quality and pollution processes
MODELING A HEAT TRACER TEST IN ALLUVIAL SEDIMENTS USING MONTE CARLO: ON THE IMPORTANCE OF THE PRIOR

Monday, 23 September 2019 16:00 (60)

In hydrogeology, deterministic model calibrations are useful to understand the influence of parameters on the considered variables or to image large-scale spatial parameter distribution. Oftentimes, deterministic solutions bias the problem with too smoothed parameter distributions leading to unrealistic transport predictions with underestimated uncertainties. Instead of predictions using an optimum parameterization in conjunction with reference data confirming the model, a realistic heterogeneity consideration is crucial for robust transport simulations and managing aquifer systems sustainable. Thus, using random generated models as multiple hypotheses (e.g. with Monte Carlo), then a hypothesis may be rejected, when the model does not confirm reference data (falsification step).

For that, the reference data set in this study is a heat tracer experiment in alluvial sediments (Belgium). Between an injection well and a pumping well 20 m apart, three observation panels are located at distances of 3, 8 and 15 m downgradient from the injection well. Each panel consists of 3 wells with screened intervals in the upper and lower aquifer parts. A deterministic calibration of the experiment on temperature data, using jointly HydroGeoSphere and PEST, hardly describes the experimental observations. The resulting spatial hydraulic conductivity distribution ($K$) is probably too smooth. Instead, 250 realizations using Monte Carlo in combination with sequential gaussian simulation for the $K$-distributions define the prior (hypotheses). For the $K$-distribution two scenarios are used: (1) a random $K$-distribution with unknown mean, variance and spatial correlation and (2) the same approach but with a downwards increasing vertical trend for the $K$-distribution, to mimic the observed increasing grain sizes of the sediment with depth.

With Scenario 1, the prior range (250 simulations) surrounds the reference data (i.e. heat breakthrough curves) for most of the experiment, but not for the tailing. The prior generated using Scenario 2 (with the vertical $K$-trend) improves the simulation of the breakthrough tailings for panel 1 and 2. In panel 3 (15 m downgradient), simulations for the lower aquifer part show significant lower peaks than measured. Scenario 1 is falsified (rejected), because the prior (250 models) do not confirm the reference data, while scenario 2 is not-falsified till panel 2 (8 m downgradient). Scenario 2 addresses the heterogeneity of the test site more realistically than all previous unsatisfying deterministic attempts. A global sensitivity analysis at panel 1 and 2 identifies then the spatial K-distribution and its variance as the most sensitive parameters. This confirms, that future efforts needed for panel 3, should focus on identification of heterogeneous patterns in the aquifer and their subsequent introduction in the model.

As a perspective, the use of a direct predictive framework (e.g. Bayesian Evidential Learning), avoiding the commonly used calibration procedure, promises robust decisions made by more realistic quantifications of the uncertainty caused by heterogeneity.

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Session Classification: Poster with refreshments

Track Classification: Topic 5.3 - Advanced modelling tools for subsurface hydrology: from the vadose zone to deep environments
Two billion people still consume drinking water contaminated with faeces. To improve this situation, it has been recognised by UNICEF and the WHO that a more rapid approach to detecting faecally contaminated drinking water is necessary. We have previously demonstrated that fluorescence spectroscopy is a significant real-time indicator of the presence/absence and number of faecal indicator bacteria in drinking waters in low-income countries of the tropics. We have also established its potential as an online indicator of faecal contamination of public water supplies in the UK. Outstanding questions remain, however, over the source of the fluorescence and its uniqueness to faecal-indicator bacteria. To address these, we sampled potable groundwater supplies in Kenya, Malawi, Senegal and Uganda across an urbanisation transect from rural Malawi through to the city of Dakar (Senegal) where pollution sources and pressures vary considerably. We report on whether the fluorescence signal in these sources is intracellular or extracellular and, in Senegal and Uganda, the ability of fluorescence spectroscopy to predict total bacteria cells and faecal-indicator bacteria.

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Session Classification: Parallel

Track Classification: Topic 5 - Tools, methods and models to study groundwater
COLD WATER INJECTIONS AS INNOVATIVE SMART TRACER TECHNIQUE IN HOT FRACTURED AQUIFERS

Friday, 27 September 2019 09:55 (15)

Robust transport simulations for sustainable management of groundwater in fractured rocks, need accurate observation data about fracture and matrix processes. In aquifers with naturally hot groundwaters (i.e., 30 °C in South India), heat injections can become difficult and cumbersome, considering strong density influences. Injecting cold water is a much more promising and innovative tracer technique. Injecting cold water reduces the energy stored in the matrix, as heat is released to the colder circulating fluid in the fractures. Thus, cold water injections can produce very informative reference data for managing hot fractured aquifers using groundwater flow and cold plume transport numerical modeling.

Heat and cold water tracer tests have been performed for the first time in Choutuppal nearby Hyderabad in South India. Sub-horizontal fractures have been intersected by 30 wells drilled in a weathered granite aquifer. A saprolite layer of in average 14 m thickness covers the fractured granite system. The natural granite aquifer background temperature varies yearly between 30 °C and 35 °C. During the experiments, the natural aquifer background temperature was around 30.3 °C. The most explored well (CH03) is used as injection well for all experiments. There, an inflatable double packer system isolates one sub-horizontal fracture connecting CH03 with a pumping well (CH12) located at a 5.5 m distance. This set-up allows successive 1-hour injections of 1000 L of hot water (∆T = +20 °C) and cold water (∆T = -20 °C).

The peak arrival times measured in CH12 are 41 minutes for heat and 51 minutes for cold water. The peak temperature difference measured in CH12 for heat is ∆T = +3.3 °C and for cold water ∆T = -2.9 °C. This is consistent with the fact that density and viscosity decrease with higher temperatures. Remarkably, cold water shows a slightly faster first arrival. It might indicate that storing energy is slightly faster initiated than releasing energy from the matrix.

First interpretations of the observed tailings show that for hot water injection, the subsequent temperature decrease (back to the background T) seems slower than the observed temperature increase after the cold water injection. It seems that cooling the matrix (i.e. reducing the energy level) is slightly more time consuming and difficult than heating the matrix (i.e. storing energy).

More experiments, e.g. repetitions of these experiments focusing stronger on the tailing for imaging matrix processes, complementing cold water tracing experiments (e.g. push-pull) and the possible parallel use of geophysical imaging tools, are ongoing. Nevertheless, the first tracer tests with cold water injections generated reference data that are very informative for further transport modeling (e.g. using Monte Carlo simulations).
Track Classification: Topic 5.4 - Innovative approaches for understanding groundwater flow systems
Passive seismic monitoring uses seismic waves generated by natural sources (wind, rivers, ocean storms, etc.) to reconstruct the temporal and spatial evolution of the subsoil. The principle of noise monitoring consists in correlating the ground motion recordings between two points to bring out the Green function over successive time windows. If the medium does not change over time, the Green’s function obtained by noise correlation is the same. Contrarily, if the environment changes, the speed of the waves will also change: Green’s function is modified. This method has successfully been applied to monitor groundwater levels of shallow aquifers.

The objective of this research project is to monitor the groundwater in the Fontaine-de-Vaucluse catchment area (>1100 km2). Water level depths average about 700 meters, with fluctuations that can locally exceed 100 metres after intense rainfall events. The geological complexity including karst and the hydrological behaviour in the Fontaine de Vaucluse aquifer constitute a major challenge for seismic noise methods. We present here the preliminary results of an ongoing seismic survey of 20 stations distributed over the catchment area. We show the ability of our network to track the changes of groundwater content due to short term episodes of recharge.

The ambition of this project is to transform seismological velocity variations into additional constraints for hydrogeological models. Several approaches are being considered, including i/ the integration of spot measurements of groundwater table variations by intra-correlation of the different components of the same station; and ii/ the integration of spatially integrated measurements between two different seismological stations. This effort requires poroelastic modelling of speed variations and a correct knowledge of geology. This knowledge then makes it possible to specify the depth of the measured speed variations, and therefore the position of the groundwater table at our different measuring points. We then have virtual piezometers, complementary to the few real piezometers, whose water level measurements can be compared with each other and with the results of the models of flow. Thus, the contribution of new dynamic measurements from the virtual piezometers will help to specify (i) the large-scale permeability and porosity field, (ii) the hydrological impact of certain discontinuities (faults and low-permeability lithological levels, probably flow barriers) and the Banon and Sault ditches.

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Diffuse recharge variations and megadrought in groundwater resources of Central-Southern Chile (Nilahue Aquifer, O’Higgins region)

Central-Southern Chile knows a hydrological balance deficit and water resource issues are starting to impact drinking water supply. This study assesses the hydrogeologic resource variations in the semi-arid Nilahue watershed (1390 km²) in the Coastal Cordillera (O’Higgins region) where precipitation over the 1986-2016 period averages 647 mm yr⁻¹ (vs PET: 1310 mm yr⁻¹). Using the available monthly hydrological data, provided by DGA and (CR)² (precipitation, temporary stream discharge and PET), the study addresses diffuse groundwater recharge through a hydrological water balance modeling over 1986-2016 period at both, monthly and annual time-scales. At the monthly time-scale, recharge is highly variable in time and occurs for precipitation rates greater than 53 mm per month, between May-August (up to 507 mm yr⁻¹; June, 2000). Although monthly precipitation can exceed previous value, recharge may not occur when soil water-reserve is low due to previous dry months. At the annual time-scale, recharge ranges from 0 mm yr⁻¹ (e.g. 1998, 1990) to 705 mm yr⁻¹ (2002), averages 277±224 mm yr⁻¹ during 1986-2016 period, and occurs for annual precipitation rates (P) greater than 360 mm yr⁻¹ according to the following relation: Recharge=0.96*P-343.5 (R²:0.9). For both time-scales, a clear relation in time is observed between recharge events and temporary surface discharges in the Nilahue river validating hydrogeological modeling. But during the 2010-2016 megadrought in Central-Southern Chile, precipitation decreased 28% (Nilahue watershed) leading to a drastic decline in the (i) frequency of recharge events and (ii) annual recharge rate (i.e. 141 ± 57 mm yr⁻¹). Climate forecasts indicate more frequent megadroughts in Central-Southern Chile for 2010-2050 period. Thus, this study highlights an alarming decline of the diffuse groundwater recharge leading, together with an increasing water demand, to a strong risk of water resource depletion.

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Session Classification : Poster with refreshments

Track Classification : Topic 9 - Groundwater and socio-economic development in Latin-America
RANDOM FOREST MODELLING OF GLOBAL GROUNDWATER ARSENIC

Thursday, 26 September 2019 17:30 (15)

Naturally occurring arsenic groundwater contamination affects aquifers around the world. Odorless and tasteless, just trace amounts of arsenic can present a hazard to human health. Since arsenic is relatively difficult to detect, it is not routinely measured in groundwater quality analyses. In order to better assess the global extent of arsenic groundwater contamination, we have used random forest modeling to create a prediction map of areas likely to contain naturally occurring concentrations of arsenic in groundwater exceeding the WHO’s guideline of 10 µg/L for drinking water. We will present this map as well as the modelling procedures behind it.

Random forest modeling is a highly effective statistical learning method based on an ensemble of decision trees that has seen much use in classification problems for environmental applications. In this case, we have trained and tested a random forest model on ~120,000 known groundwater arsenic measurements trying more than 20 various geology, soil, climate and hydrological parameters taken from the latest publicly available global datasets. Specifically, 80% of the arsenic concentration dataset was used for model training, while the other 20% was retained for testing and verification. 1001 individual trees were grown by bootstrap aggregating (bagging) a random selection of the training dataset and making a random subset of variables available at each branch split. So doing helps reduce variance while maintaining low bias in the random forest model. The final prediction model comprises the average votes of these 1001 trees for the predictor variables used.

Our highly accurate, 1-km resolution random forest model represents the most sophisticated characterization of arsenic contamination in aquifers around the world. In particular, it utilizes considerably more and higher resolution data than does the 2006 Amini et al. global groundwater arsenic model. The new map can be used by water managers and other government and non-government agencies to prioritize area for groundwater quality testing. Furthermore, it works toward Sustainable Development Goal (SDG) 6 with regard to the provision of safe drinking water.

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Session Classification : Parallel
Track Classification : Topic 8 - Groundwater quality and pollution processes
What hydrogeology can learn from data science in terms of reproducible research

Tuesday, 24 September 2019 12:30 (15)

Programming and machine learning play an increasingly important role as part of research methods in most scientific disciplines, including geosciences, as the volume of data collected increases exponentially. In hydrogeology, it is used for data pre-processing, analysis, prediction, or visualization. However, when trying to apply or adapt promising methods to one’s own data, it is often difficult or even impossible because of poor documentation. Therefore, it is essential to make use of state-of-the-art methods for the documentation of research methods that include code to maximize reproducibility, transparency and the ability of collaboration in hydrogeology. The quality of the documentation is also fundamental for a fast transfer of knowledge, methods and related errors.

This state-of-the-art documentation has been developed and applied for several years mainly in computer science and data processing. At the lowest level, this includes the supplementary publication of well-named and structured script files according to ideally existing conventions and at the highest level the publication of a so-called Jupyter notebook on a development platform such as Bitbucket, Github or others. Easily reproducible research not only requires high-quality documentation, it begins with a shift from hard-to-document analysis tools such as spreadsheets to programming languages for data science and geospatial data processing. The most common documentation tools from neighbouring disciplines will be presented and discussed to make hydrogeological research more accessible and accelerate knowledge transfer. Especially because speed in gaining new insights into the consequences of climate change is a key component.

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Session Classification : Parallel

Track Classification : Topic 1 - Groundwater assessment and management
Fault zone in massive limestones: karstified or not karstified contexts?

Thursday, 26 September 2019 15:30 (15)

In the Mediterranean region, the most productive carbonate aquifers with significant underground reserves are mainly located in massive limestones or dolomites of the Jurassic or Cretaceous age. During their geological evolution, these carbonate formations have undergone various tectonic phases that structure such reservoirs, by folds, faults or fractures. While the scientific community of hydrogeologists agrees that the presence of fractures contributes to the occurrence of karstification and that the development of karst networks depends on the existence of these fracture networks in interaction with the various planes of stratification, many issues are still to be resolved regarding the impact of major faults on groundwater flows in such environments: (i) do these act as an impervious boundary, especially when these structures are put into contact the main reservoir with an impervious layer? - (ii) or is it a preferential pathway for groundwater flows, particularly with the development of karstic drains within these major fault zones? - (iii) or finally, do they allow flows only through the fractures located in the damaged zones of these faults, in lack of karstification.

This project is part of the study of the dynamic analogues, and concerns in particular the characterization of fluid transfers within a fault zone in a carbonate environment. In such environments, a key issue remains, which concerns the occurrence of karst or not, with or without an impact on groundwater flows within and/or through a fault zone.

In the North of Montpellier, about 20 sites located in Jurassic and/or Cretaceous aquifers were investigated in order to characterize the flow patterns within major faults that affect these reservoirs. Through the example of the Kimmeridgian-Berriasian reservoir drained by the source of the Lez which supplies Montpellier, and which is affected by many major faults (Matelles-Corconne, Saint-Clément faults...), we have characterized the hydrogeological behaviour of the latter. The aim of this study is therefore to present how, in the case of massive carbonate media, - (i) the faults are karstified or not, and - (ii) how flows occur through and within them.

The authors thank TOTAL for funding this R&D project and giving permission to publish this paper.
Groundwater quality prediction maps for risk-based decision making

Sampling and analysing groundwater for the presence of inorganic contaminants relevant to human health (e.g. arsenic, fluoride, nitrate) is time-consuming and costly, especially in regions with weak infrastructure. Predictive mapping and modelling techniques exist that have the capability to identify regions where aquifers are particularly vulnerable to certain contaminants, both from geological or anthropogenic sources. Over more than 10 years of applied research, we have refined an approach by which measurements of contaminants in groundwater are correlated with widely available spatial data of environmental parameters (e.g. geology, soil properties, climate, population density) using statistical and machine learning methods. The resulting hazard maps predict areas of contaminated groundwater by giving the probability of contaminant concentrations exceeding a given threshold value. Examples of produced maps include successful predictions of arsenic in groundwater for South-East Asia, China, Pakistan and Burkina Faso, and fluoride in India. Recently, we have also started assessing and mapping the vulnerability of aquifers to surface contaminants such as nitrate using these techniques.

To facilitate access to these maps and associated data, we have developed the Groundwater Assessment Platform (GAP), accessible at www.gapmaps.org. GAP is a free, interactive online GIS platform for the mapping, sharing, analysis and statistical modelling of groundwater quality data. Maps of existing data and models can be viewed by all users, whereas a free login enables registered users to upload and process their own data in a secure environment and make use of the statistical modelling functionalities. Prediction maps of point data can be generated by means of gridding (inverse distance or nearest neighbour) or logistic regression, using either publicly available spatially continuous global datasets of various environmental parameters or one’s own raster or polygon data as predictor variables. Despite statistical programming packages offering more options for manipulating and modifying data and models, the prediction maps produced using GAP are remarkably similar and require substantially less time to generate, due to GAP’s simple, quick-to-use modelling interface.

Such contaminant hazard maps provide valuable baseline information for practitioners and scientists to help prioritize locations for detailed water quality surveys, to target specific contaminants and to site new boreholes. They are also useful in estimating the number of people potentially exposed to contaminants in drinking water and thereby at risk to related diseases such as arsenicosis or fluorosis.

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Session Classification : Poster with refreshments

Track Classification : Topic 5 - Tools, methods and models to study groundwater
How to model the impacts of land use changes in karstic environments: Model development, parameter dimension reduction and uncertainty quantification

Thursday, 26 September 2019 17:15 (15)

Lumped hydrological models are tools commonly used in karst water resource management, however, their parameters cannot be obtained from field measurements and need to be estimated by model calibration. In general, the more hydrological processes are represented in a lumped parameter model, the higher the dimensionality of the parameter space. In particular, a large number of parameters is needed if we implement a karst hydrologic model that can reproduce the effect of land use changes.

We recently developed the LuKARS model (i.e. a hydrotope-based lumped karst aquifer model) with the particular aim to investigate the hydrological impacts of land use changes in the karstic system of the Kerschbaum springshed in Waidhofen a.d. Ybbs (Austria). The implemented model was calibrated for the years 2006 – 2008 and comprises 21 calibration parameters for 3 hydrotopes. While the model adequately reproduces the observed hydrological impacts of the land use changes, the model output uncertainties are high due to the 21-dimensional parameter space. For this reason, we applied the recently proposed active subspace method to the LuKARS model to investigate possibilities of reducing the high-dimensional initial parameter space and to quantify the related model uncertainties. The active subspace method searches for orthogonal directions in the parameter space that are relevant to update a defined prior to a well-constrained posterior parameter distribution. If relevant directions are identified, a lower dimensional subspace can be created which can be used to simplify the higher dimensional problem.

Applying the active subspace method to the LuKARS model of the Kerschbaum spring, we were able to investigate the model structure and model parameter uncertainties. In this regard, we show that the space covered by each hydrotope as well as its specific hydrological variability are decisive to reproduce the hydrological dynamics of the measured karst spring discharge. Moreover, relevant parameter directions were identified by the active subspace method, leading to a dimension reduction of the initial 21-dimensional parameter space to a 4-dimensional one. Using the model with a 4-dimensional parameter space, we still can reproduce the hydrological impacts of the land use changes in the Kerschbaum recharge area. Thus, we conclude that the LuKARS model is a robust modeling approach for assessing the effects of land use changes on karst water resources. Moreover, the active subspace method is a promising tool to reduce the uncertainties related to the structure and the parameters of lumped karst aquifer models.

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**Session Classification:** Parallel

**Track Classification:** Topic 7 - Karst Hydrogeology
Preliminary quantification of surface water inputs to the Ozama Wetlands National Park (Dominican Republic)

Friday, 27 September 2019 10:25 (15)

Wetlands are hydrologically sensitive ecosystems to the impact of anthropic actions and natural changes. At the same time, there is a close relationship between the functioning of wetlands and their capacity to provide services to human well-being and other ecosystems, so that certain modifications of the hydrology of wetlands have a significant negative impact on the human societies of their environment. Knowledge of hydrological functioning and the hydrodynamic and hydrochemical characteristics of surface and underground water of wetlands is essential to achieve sustainable water management, preserve the environment and evaluate the response of the environment to the impacts produced by human actions and natural changes. The Ozama Wetlands National Park (OWNP) is one of the most important in the Dominican Republic and around 344,000 people live in their surrounding area. The water balance of the OWNP is being studied by means of different methods to quantify the atmospheric, superficial and subterranean input and output water flows, and to identify which are the main mechanisms controlling the wetlands hydrology, its state of functionality (natural or altered) and the main factors that can induce changes in their hydrological regime. The preliminary results of the quantification of the main surface water inputs and outputs to the OWNP by current meter in the months of April (wet season) and December 2018 (dry season) are presented. In the Ozama River, the main river of the basin, input flows to OWNP were measured to amount 7 and 3 m³/s respectively (both months). In the Yabacoa River, the second stream contributing to the OWNP, 6 and 7 m³/s were measured for the same months. The only surface outlet of the OWNP is the Ozama river. The output flows measured in both months were 17 and 19 m³/s, respectively. The difference between incoming and outgoing measured flows reveals the existence of significant contributions to the wetlands of the OWNP not measured, which must be quantified.

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Session Classification : Parallel

Track Classification :  Topic 9 - Groundwater and socio-economic development in Latin-America
Evaluation of water provisioning services in the upper Guayllabamba River Basin applying the InVEST water yield model

Ecosystem services have been highly underestimated in decision making, in the formulation of economic policies, in markets, prices, production habits, consumption and land use practices. Population growth, the expansion of the agricultural frontier and changes in land use have affected water sources and ecosystems. Therefore, the aim of this study was to evaluate the water provisioning services in the upper Guayllabamba River Basin using the Integrated Valuation of Ecosystem Services and Tradeoffs (InVEST) model. The study area is located in Ecuador’s northern inter-Andean region and occupies an approximate area of 6846.67 km² with an altitudinal range between 637 to 5897 m.a.s.l. For the water yield model, various sources of information were used: i) a network of 133 pluviometers with historical records from 2001 to 2014, from the Instituto Nacional de Meteorología e Hidrología (INAMHI), the Empresa Pública Metropolitana de Agua Potable y Saneamiento (EPMAPS), the Regional Initiative for Hydrological Monitoring and Andean Ecosystems (iMHEA), The Quito Water Fund (FONAG) and the Secretaría del Ambiente (SA) ii) unprocessed and corrected satellite precipitation data (TRMM V7) iii) annual reference evapotranspiration (ETo) iv) flow data in 12 sub-basins, and v) land use/land cover. The InVEST model executes a spatially distributed surface water balance at a scale of 1 km² with an annual time scale. The results of the study have been represented in water yield maps and can support the delimitation of water conservation zones and identify the properties that could be purchased in the future by EPMAPS, FONAG and other institutions allowing them to guard and focus on the development and sustainable management of water resources. Water yield can reach values as high as 1500 mm/year in the high elevation areas near mountains such as Antisana (5704 m.a.s.l), Cayambe (5790 m.a.s.l), Pichincha (4784 m.a.s.l). Similarly the smallest water yield values can be as low as 500 mm/year in the northwest part of the basin and Guayllabamba Medio sub-basin (637 m.a.s.l).

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Session Classification : Poster with refreshments
Track Classification : Topic 1 - Groundwater assessment and management
Physiographic and climatic controls on groundwater dynamics in Southern Germany

The presented study analyses the relationship between temporal dynamics of local groundwater levels and climatic as well as physiographic controls. The analysis is based on observational data from 340 wells in Southern Germany with ten-year daily groundwater hydrographs. Wells tap confined and unconfined sand and gravel aquifers from mountain valleys to more extensive lowland alluvial aquifers. Groundwater dynamics at each location are summarized with 45 indices describing groundwater hydrograph features of structure, shape and distribution. Besides borehole log-derived geologic information, local and regional morphologic features, topography-derived boundary conditions as well as climatic descriptors were derived for each well. Correlation analysis was carried out between the indices and the 54 candidate controls (geologic, morphologic, boundary and climatic). These correlations allowed identifying indices and controls with the strongest relationship. Global regression relationships were established by mining the data for associations between dynamics and controls with forward stepwise regression. Models were selected using significance testing based on selective inference with selection-adjusted p-values. The study shows that groundwater dynamics are most strongly linked to geology and boundary conditions and secondarily to climate, but also to some morphologic features. Those multiple linear regression models with low to moderately high coefficient of determination (R² = .2 - .6) are in agreement with general process understanding linked to groundwater dynamics. This systematic investigation of the relation between a large number of candidate controls and groundwater dynamics may provide guidance for prioritizing the study of controls on groundwater dynamics. Furthermore, the study suggests that statistical regionalization of groundwater dynamics in ungauged aquifers based on map-derived physiographic and climatic controls can be feasible.

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Session Classification : Parallel
Track Classification : Topic 5.4 - Innovative approaches for understanding groundwater flow systems
Groundwater Management - A Perspective from Alberta, Canada

Monday, 23 September 2019 11:45 (15)

Fresh groundwater is a renewable resource and must be managed. Who should manage it: users or government? Or both? How should it be managed? Is groundwater scarcity perceived or real? What will happen as the climate changes?

To manage something means to control it. The natural groundwater cycle includes recharge to, storage in and natural discharge from an aquifer – parameters which, at best, can only be estimated. Although these natural parameters cannot be managed, the human impact on the groundwater cycle – that is, the removal of groundwater from the aquifer, and the impact of that removal on the water level – can be measured, and therefore managed.

Meaningful groundwater monitoring is necessary in order to manage groundwater resources. Aquifer tests are a guide to the availability of groundwater at a point in time, but groundwater monitoring allows us to assess how much groundwater is available on a sustained basis and provides data to help predict the effects of climate change on the resource. Meaningful groundwater monitoring includes using calibrated instruments to measure hourly discharge and at least hourly water levels from pumped water wells, and hourly water levels from observation water wells.

With today’s technology, meaningful groundwater monitoring is affordable, with near real-time analysis. The data, collected at low cost, are reliable and accurate – and therefore essential in the management of the groundwater resource.

The best time to start groundwater monitoring was 50 years ago; the second-best time is TODAY. Examples from Alberta will be provided.

If you don’t measure it, you can’t manage it.

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Session Classification : Parallel

Track Classification : Topic 1 - Groundwater assessment and management
The current study proposes a methodology for groundwater resource evaluation and hydrogeological exploration specifically designed for natural mineral water projects. It is applied to the recharge area of the Guarani Aquifer System, State of São Paulo / Brazil. In that area, this aquifer is represented by Botucatu (Upper Jurassic - Lower Cretaceous) and Pirambóia (Triassic) sedimentary formation. Part of the studied area is recovered by Serra Geral formation (Early Cretaceous) mainly basaltic and basaltic-andesitic litotypes. All the above-mentioned litotypes are located within the Paraná Sedimentary Basin (Cretaceous – Ordovician).

It is common sense that natural mineral waters of low mineralization are preferred by Brazilian consumers due to their specific taste. In addition, capacity high enough to supply a factory and low exposure to anthropogenic risks regarding both quality and quantity (contamination and superexploitation respectively) are also important characteristics to be considered for natural mineral water exploration purpose.

The Transnational Guarani Aquifer System is the second largest in size and capacity in the world. It is located in the South American countries of Argentina, Paraguay, Uruguay and Brazil. Its specific hydrogeological characteristics favor robust projects for the natural mineral water market (bottled water industry). In its outcropping zone, in the State of São Paulo, Brazilian territory, boreholes flow rates are in the order of 20 to 40 m³/h, with specific capacities superior to 4.0 m³/h/m. Hydrochemistry is of low to moderate mineralization, with predominating bicarbonated-magnesium and calcium-magnesium facies mainly oligomineralized as well as fluorinated. The pedological and geological context of this area, as well as flow paths in the aquifer, protect the groundwater and reduce quality risks (physico-chemical and microbiological).

The main parameters used for the hydrogeological prospecting methodology are listed below:
I) Lithology of Aquifer: Sandstones of the Pirambóia and Botucatu Formations - as reservoir
II) Hydrodynamic parameters: Specific capacity and thickness of aquifer
III) Hydroclimatological parameters: Analysis of the regional recharge
IV) Aquifer protection: pedology and presence the overlying basalts of the Serra Geral Formation
V) Hydrochemistry: Hydrochemical profile and mineralization (residence time, characterization and classification)
VI) Land Use: Risks related to interferences (quantity and quality)
VII) Economic parameters such as distance from main consummation area and main infrastructures such as highways.

Other parameters such as Slopes, Geomorphology, Drainage Density are used as complementary data.

All these parameters were input as vector data in a GIS, affected with ponderation coefficients and then crossed to draw groundwater potential maps. Various maps were issued and discussed with decision makers according to the weight they want affect to the various hydrogeological and economic parameters.

This methodology is effective and can be used in other hydrogeological contexts as far as business strategies and local specificities are considered.
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Session Classification : Parallel

Track Classification : Topic 9 - Groundwater and socio-economic development in Latin-America
Modelling water stable isotopes to trace the variability of groundwater recharge

Tuesday, 24 September 2019 15:30 (15)

Soil physical models are widely used to describe water flow and solute transport in the vadose zone, for example to estimate groundwater recharge. These models require accurate and precise information about the properties of the vadose zone that link fluxes with state variables, such as the soil water retention curve, the unsaturated soil hydraulic conductivity, and the solute dispersion coefficient. Typically, these properties are determined from laboratory experiments, but with low accuracy to describe field-scale processes due to spatial variability at the field scale. The inverse model approach allows optimizing model parameters by fitting simulations to observed data at the scale of interest. The majority of field-scale inverse modeling studies have used solely information about water content to determine the properties of the vadose zone. Recently, attention has been given to combining water content and water stable isotope ratio profiles to calibrate soil models based on one single field campaign.

The main objective of this study is to determine if the inclusion of pore water isotope data allows a realistic parameterization of soil physical models without the need of continuous monitoring data. The METIS code, a soil physical model including isotope transport and isotopic fractionation due to evaporation, was used. A sensitivity analysis based on Morris Sobol method was performed, and highlighted strong interactions between the parameters, reinforcing the need of combining different observation types to calibrate models. A synthetic case allowed to determine the performances of the calibration methods proposed here. Then, using soil moisture and isotope profiles of a first campaign in a multi-objective approach to optimize the model parameters, a best set of parameters was determined for a site in South of Quebec, Canada. The realism of the parameterization obtained was judged based on the ability to reproduce soil moisture and isotope profiles of a second campaign, one year later. The multi-objective function approach with calibration and validation was able to satisfactorily reproduce the two data. However, based on the result of a synthetic case, monitoring at various time water content and water stable isotope ratio, even if it is not continuous, would allow a more realistic parameterization of the soil parameters. The development of new in situ methods to easily measure in time the water content and pore water isotope composition is thus needed.

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Session Classification : Parallel
Track Classification : Topic 5.3 - Advanced modelling tools for subsurface hydrology: from the vadose zone to deep environments
Planning of Groundwater Resources Protection in Shuangyashan City

Monday, 23 September 2019 16:00 (60)

Shuangyashan City, located in the northeast of China, is the largest coalfield in Heilongjiang Province and one of the ten largest coalfields in China. In this study, hydrogeology, hydrogeochemistry, environmental hydrogeology and other comprehensive research methods were used to find out the groundwater environment of Shuangyashan City based on the specific conditions of Shuangyashan City and the previous achievements of water resources development and utilization evaluation. The groundwater resources in the planning area were calculated in detail by equilibrium method, and the internationally advanced three-dimensional visualization underground was used. Water simulation software Visual Modflow is used to simulate groundwater regime, establish groundwater flow field prediction model by numerical method, and evaluate groundwater vulnerability in planning area by DRASTIC index system method. The results show that the groundwater resources in Shuangyashan City are 13504.24m³/a, the groundwater quality is good as a whole, the vulnerability of groundwater is high as a whole, and groundwater is vulnerable to pollution. Finally, the groundwater protection area and groundwater protection target are determined synthetically. The overall scheme of groundwater protection in Shuangyashan City is put forward, and the engineering and non-engineering measures of groundwater protection are proposed.

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Session Classification : Poster with refreshments
Track Classification : Topic 1 - Groundwater assessment and management
Characterisation of geogenic controls on groundwater quality in a volcano-sedimentary aquifer in Kenya using graphical and statistical methods

Thursday, 26 September 2019 16:00 (60)

Geogenic controls on groundwater quality are often dominant but remain inadequately characterized for many aquifer systems. The volcano-sedimentary aquifer of Kisumu (Kenya) is used widely to provide safe water to the informal settlements and acts as a strategic, supplementary supply to the city during interruptions in service from the main piped water supply network drawing from Lake Victoria. Little is known, however, of the geogenic controls on groundwater quality in the Kisumu aquifer. We characterize the origin and composition of solutes in groundwaters sampled from the Kisumu aquifer using a range of techniques. Classical graphical methods (i.e. Durov, Piper, Schoeller, Stiff and Ternary plots) were used as interpretative tools of the main hydrogeochemical processes whereas principal component analysis (PCA) and hierarchical cluster analysis (HCA) methods were used to assess hydrochemical variations and water types. An agglomeration schedule with five cluster solutions and between-groups linkage method of clustering using the squared Euclidian distance was employed. Variables were standardized to z-scores so that each variable contributed equally to the clusters. The study identifies three main groundwater geochemical signatures in the Kisumu study area: cation exchange (Ca-Na, Ca-Mg) between aqueous and solid phases, the chemistry of recharge water, and groundwater mixing. The concentration of major ions in groundwater varies with geology and also seasonally. The dominant water facies is Na-Ca-HCO3 type; other hydrochemical facies include Ca-Mg-HCO3 and Na-HCO3. Hydrochemical plots suggest that dissolution of carbonates and halite are the other major chemical processes, in addition to cation exchange, that control the groundwater chemistry in the Kisumu aquifer. Hierarchical cluster analysis of the main cations and anions discriminated satisfactorily the various water types in the study area.

Key words: Groundwater quality, geogenic processes, Hierarchical cluster analysis, Kisumu

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Session Classification : Poster with refreshments

Track Classification : Topic 5.2 - High island hydrogeology
Advancing Groundwater Sustainability within the Water-Energy-Food-Climate Nexus: Transferring Knowledge between Developed and Developing Countries

Monday, 23 September 2019 16:00 (60)

Water, energy, and food are the most critically important resources for society, particularly in meeting Sustainable Development Goals (SDGs). The demand for these resources will increase in future decades because of climate change, population growth, and socioeconomic forces. This growing demand is creating more trade-offs and conflicts, particularly among groundwater resources and stakeholders in both developed and developing countries. These conflicts have exacerbated the challenges of managing sustainable groundwater and coupled food and energy resources. This complex relationship between water, energy, and food resources and climate change is called the water-energy-food (WEF) Nexus. There is a research need to quantify the impacts and feedbacks of the WEF Nexus and identify how those concepts may help scientists and resource managers design optimal groundwater sustainability (WEF-GW Nexus) plans to best meet diverse stakeholder interests. Our WEF-GW Nexus project uses a transdisciplinary approach that integrates different knowledge systems from developed and developing countries; including those from academic researchers, early-career scientist and students, farmers, and other groundwater users and practitioners from rural and urban communities, local resource agencies, and other stakeholders. We will also hold training and knowledge transfer workshops, creating a dialogue about science and research to advance management, policy, and stakeholder engagement that leads to sustainable groundwater within the WEF-GW Nexus. To address the identified lack of WEF-GW studies, the WEF-GW Nexus project has established a global collaboration in 2019 of dozens of participants from three continents, and is supported by the International Geoscience Programme and UNESCO-GRAPHIC. The WEF-GW Nexus collaboration targets groundwater basins on three continents —Africa, America, and Europe — containing vast groundwater resources with an estimated dependence of tens of millions of people. We will present the WEF-GW Nexus project, show examples from groundwater basins, and discuss collaboration possibilities to integrate groundwater information from these regions.

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Session Classification : Poster with refreshments

Track Classification : Topic 2 - Groundwater and climate change
Assessment of spatial varying relations between nitrate contamination and land uses using geographical weighted regression model

Thursday, 26 September 2019 16:00 (60)

Groundwater pollution by nitrate has been one of the major water quality problems against the sustainable use of water resources in Jeju volcanic island. The study area is characterized by spatially varying distribution in nitrate contamination, environmental and land uses features, which is considered as a main challenge restricting advanced groundwater management. Jeju Island has been experienced by drastic changes in land uses over the years, increasing threats of groundwater vulnerability to nitrate pollution is expected. Therefore, we performed the geographical weighted regression (GWR) model to predict nitrate behaviors in groundwater based on various categories of land uses in consideration of spatial variability. Also, a comparison of model performances between conventional OLS (ordinary least square) and the GWR was evaluated in this study. Total 5,840 groundwater NO3-N data from 2,603 wells (2007–2011) was used for the regression models as a dependent variable and for independent variables, 8 categories of land uses in 2009 (urban, crop field, orchard, greenhouse, forest, grassland, water and road) were utilized. The GWR showed higher R2 values (0.41–0.61) with lower AICc levels (113.16–176.75) for all independent variables. R2 (0.02–0.54) and AICc (129.45–244.85) obtained by the OLS showed a lower prediction ability than the GWR, which means that spatially varying regression model is able to explain the NO3-N variance more reliably. Based on the GWR model, the crop field highly degraded groundwater quality by nitrate in the western part and the orchard in southern area showed a positive impact on the nitrate contamination than the other regions. In northern and western parts, an increase in the greenhouse land uses would highly elevate the NO3-N levels. This study highlighted that improved groundwater management plans can be achieved by an application of the GWR based on profound understanding of spatially heterogeneous relationships of land uses on the nitrate contamination.

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Session Classification : Poster with refreshments

Track Classification : Topic 5.2 - High island hydrogeology
Stochastic knowledge integration for groundwater exploration in data scarce areas

Monday, 23 September 2019 12:30 (15)

We have developed a systematic probabilistic framework to spatially assess the potential for sustainable groundwater development. The workflow starts by explicitly defining sustainable groundwater extraction, in our case study, a groundwater abstraction that can provide 1ML/d for 10 years with a salinity of less than 2500 mg/L without causing a drawdown of more than 5% of the saturated thickness at 1m from the borehole.

The methodology is applied to groundwater exploration in the Anangu Pitjantjatjara Yankunytjatjara (APY) Lands in central Australia. In this arid region, a crystalline basement is covered with regolith and a vast system palaeovalleys that are filled with sediments. Both the regolith and the palaeovalley systems are known to host aquifer systems. An ensemble of interfaces that define the boundaries between the basement and the overlying weathered rocks and palaeovalley sediments is generated with a Bayesian Data Fusion methodology to ensure they are consistent with the available borehole, airborne electromagnetic and digital terrain information. The surfaces defined by these interfaces are combined with probability distributions of hydraulic conductivity and storage to create ensembles of equivalent transmissivity and storage. A similar procedure is used to generate ensembles of salinity that are consistent with the available knowledge of salinity distribution across the region.

Gridded water balance equations, in combination with the Theis equation, allow the rapid generation of ensembles of sustainable pumping volumes from these stochastic grids of hydraulic properties and salinity. The ensembles provide the probability of locating areas where the requirements of sustainable groundwater extraction are met.

The integration framework not only allows to rapidly identify prospective zones for sustainable groundwater extraction, it is transparent, can be iteratively and locally updated when new information becomes available.

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Session Classification : Parallel

Track Classification : Topic 1 - Groundwater assessment and management
Groundwater is the most precious and irreplaceable natural resource, and understanding groundwater quality is of paramount importance for effective groundwater management. Change in the groundwater chemistry due to mining, anthropogenic sources and farming may change the quality and suitability of groundwater.

The study area is located in the Northern Cape Province, South Africa, and is underlain by Proterozoic rocks of the Namaqua-Natal Metamorphic Province, also referred to as the Namaqua Sector. The rocks in the Namaqua Province comprise a variety of metamorphic rocks, and different types of schists as well as Cenozoic sediments. The area is a typical semi-arid area with mountainous areas receiving higher rainfall than the arid lowland due to orographic effects. Some granitic rocks as well as surficial sediments in the Namaqualand contain high uranium values.

Exploration of surficial uranium deposits in the Namaqualand region began in the early 1970s, and then in the mid-1970s there was a discovery of surficial and granitic uranium occurrences which resulted in major exploration. Many studies in the area have been conducted on the quality of groundwater and its impact on human health but there are no studies related to the high uranium values in the groundwater of Namaqualand.

This study aims to evaluate the water quality in Namaqualand region and, subsequently, use the groundwater chemistry to delineated potential areas for surficial uranium deposits. Fieldwork was done in July 2017 and a total of 85 water samples were collected from existing boreholes in six different catchments. Physicochemical properties (TDS, EC, pH, DO, Eh, and salinity) were measured on site and samples were taken to the laboratory and analysed for major ions and trace elements.

Speciation diagrams were plotted using the Eh-pH data to understand the dominant uranium species in the water samples.

Groundwater of the area is alkaline, with high elevated concentrations of EC and TDS. The predominant water types are found to be Na-Cl, Na-HCO3 and Mg-HCO3 followed by water types Na-SO4 and Ca-HCO3. The results indicate a large number of groundwater samples with high uranium values above the South African water quality guidelines of 1.5 µg/L. This poses health risk such as cancer or radiological related diseases to communities living in, and around the study area. Data analysis shows that in the presence of carbonates, uranium mostly occurs in solution as UO2(CO3)22- field with few samples also plotted as UO2(CO3)34-. More sampling of groundwater is recommended to conduct a study on medical geology and passive treatment of uranium in the area.

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**Session Classification :** Parallel
Track Classification: Topic 8 - Groundwater quality and pollution processes
Evaluation of the in situ behavior of a non-electrolyte solution using fluorescent dye tracers

Thursday, 26 September 2019 15:15 (15)

Background
When a non-electrolyte solution, such as an organic substrate solution used in thermally enhanced bioremediation is injected into the ground, it is necessary to control a predetermined concentration in-situ. However, since the solution is non-electrolyte, continuous measurement, control and management of the concentration in situ is difficult. In this study, a fluorescent dye was mixed with the organic substrate solution and injected into the ground. Fluorescent dyes can be measured in situ and have been widely applied as tracers for groundwater flow investigations. A previous study confirmed that the fluorescent dye moves with the non-electrolyte solution in the ground. In this study, we attempted to indirectly evaluate the behavior of the organic substrate using the fluorescent dye tracer and found a significant correlation in the concentrations of the fluorescent dye and the organic substrate solution.

Methodology
The purpose of this study was to confirm whether fluorescent dyes can be applied as a tracer for evaluating the concentration of the non-electrolyte solution. A field experiment was carried out in silty fine sand in Japan. The aquifer at the test site extended from 10m below ground level and was partly surrounded by sheet piling to a length of 9.2m, a width of 10m, and a depth of 16m. Water circulation was controlled by two injection wells and two pumping wells. The fluorescent dye Eosin Y and the organic substrate solution were injected into the ground at a constant flow rate for over 80 days. Groundwater was periodically sampled from multiple observation wells to measure the concentration of Eosin Y and the total organic carbon, as the concentration of the organic substrate solution.

Result
In this study, we show that the behavior of a fluorescent dye and non-electrolyte solution in the ground is highly correlated. The viability of using a fluorescent dye to indirectly assess the concentration of the non-electrolyte solution was demonstrated. In addition, the difference in arrival time of the fluorescent dye and the non-electrolyte solution at the observation points were discussed, focusing on their adsorption and decomposition characteristics as well as the heterogeneity of the ground.

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Session Classification : Parallel

Track Classification : Topic 8 - Groundwater quality and pollution processes
Development of a protection concept for the Dong Van Karst area as basis for a sustainable drinking water supply, Northern Vietnam

Thursday, 26 September 2019 11:15 (15)

Approximately 40% of the world’s population faces water shortage. The situation is particularly challenging in subtropical karst areas with a pronounced dry season, where the lack of surface storage capacity and the difficulty of accessing groundwater cause serious seasonal supply shortages. Additionally, water resources in karst regions are highly vulnerable to contamination due to rapid infiltration and transport in the conduit network. Innovative and locally-adapted water resource protection strategies are therefore required in these regions.

Defining adequate water resource protection zones requires considering many hydrogeological factors. In large emphasized text and geologically heterogeneous catchments, large amounts of data are required. In remote and socio-economically weak regions, the necessary data is usually not available. To address these problems, we demonstrate a simplified approach to develop a pragmatic, sustainable drinking water supply protection plan for a karst catchment in the Dong Van region of Vietnam. This effort is part of the KaWaTech Solutions water resources project.

First, the catchment area was delineated by tracer tests. Next, we characterized microbiological contamination with faecal bacteria, and measured the particle-size distribution (PSD) at several sampling sites in the catchment. Based on these preliminary investigations, we selected a subset of locations – springs, swallow holes and surface runoff – to carry out high-resolution measurement campaigns to further characterize PSD, turbidity, total organic carbon (TOC), colored dissolved organic matter (CDOM) and E. coli concentration. Using these data, we determined flow velocities and were able to localize and characterize contamination hotspots in the catchment area. The results show three types of temporal water-quality variations: (i) seasonal variations, i.e. higher fecal bacteria levels in the rainy season than in the dry season; (ii) event-related variations caused by precipitation events; (iii) diurnal fluctuations in water quality at the principal drinking water abstraction site due to the release of untreated wastewater, especially in the morning and evening hours. The fluctuations of PSD, turbidity and TOC are correlated with each other. However, influx in the catchment area from homogeneously flowing springs with constant hydrochemical conditions minimizes and dampens the fluctuations.

Based on our investigations, we developed a plan to improve drinking water quality at the water pumping system. We focus on delineating catchment areas relevant for drinking water protection, and on building a hydrogeological model that can be used to develop a sustainable protection plan. Plans for future drinking water treatment and an early-warning system for spring water contamination will rely on our characterization of the highly variable particle load, as well as the microbial and hydrochemical water quality in the catchment and in the immediate inflow to the water pumping system.

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Session Classification : Parallel

Track Classification : Topic 7 - Karst Hydrogeology
Monitoring the groundwater levels is required to predict groundwater drought and mitigate its impacts, so as to ensure sustainable water supplies and protection of the aquatic ecosystems. The quantitative status of the groundwater resource is assessed against specific groundwater thresholds levels, which constitute trigger levels that initiate and/or terminate management actions, e.g. early warning, enforcement of water restrictions, emergency responses, etc.

While a vast majority of the published literature is proposing methods and indicators to characterise hydrological droughts, such as the threshold level method on river flow time-series or quantifying the rainfall deficit, very few are addressing the groundwater drought. In addition, methods suitable for hydrological time-series, mostly derived from statistical analyses, are seldom applicable to groundwater level time-series, because their characteristics do not fulfil the basic hypotheses for such analyses: due to aquifer inertia, groundwater level time-series are commonly auto-correlated, featuring significant trends and shifts, presenting data gaps and covering a relatively short time span. One notable exception is the recently developed Standardised Groundwater level Index (SGI), based upon the same methodology as the Standardized Precipitation Index (SPI). It can be applied to all type of aquifers, including those with multi-years cycle or displaying strong piezometric trends, and offers promising perspectives for the study of extremes events.

Such study is currently carried out in the Grand-Est region in France to improve the existing drought management trigger levels. It aims at: (i) characterizing each groundwater level time-series from the main aquifers of the Grand-Est region; (ii) establishing clusters of piezometers based on similar behaviour after a prolonged rainfall deficit; and (iii) proposing relevant drought management threshold levels determination methods for each group.

For each time-series, in addition to basic univariate exploratory data analysis (EDA), the correlogram, the periodogram, the recession curve analysis, the SGI and its correlogram are computed. Correlations between the SGI and the SPI are assessed to characterize the potential relationship between a prolonged rainfall deficit and groundwater drought.

Several parameters are tested to determine relevant groundwater indicators and thresholds, including:

- The mean of the mean annual minimum (MAM for groundwater time-series, by analogy with the MAM for river flows) on a monthly groundwater level time-series;
- The MAM-5 (5-years return period) when a statistical analysis is possible;
- The SGI calculated for a period relevant to the aquifer’s dynamic (e.g. 1 month, 3 months, 6 months, etc.).

Statistical tools are developed in the R environment and will be made available. Methods to determine groundwater level indicators and related drought threshold levels are formulated to each identified group of piezometers of the Grand-Est region. Thresholds levels are applied to documented historical drought episodes to test their relevance and robustness.

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Session Classification : Parallel

Track Classification : Topic 1 - Groundwater assessment and management
An improved DRASTIC-based groundwater vulnerability assessment using particle swarm optimization (PSO) algorithm

Tuesday, 24 September 2019 12:15 (15)

The sustainability of groundwater resources is being threatened by overexploitation, anthropogenic influences and mismanagement. Considerable intensification of groundwater demand from negligible recharged aquifers in arid and semiarid regions, has underlined deterioration of groundwater level, thereby making aquifer systems more vulnerable. Groundwater vulnerability assessment, as a worldwide tool, deploys hydrogeologic conditions to predict vulnerable areas in order to support groundwater protection. This study aims to represent a comparative account of optimized DRASTIC-based groundwater vulnerability in Qazvin plain, Iran. The inherent drawback of DRASTIC framework approach is the subjectivity in assigning weights/ratings for each hydrogeological factors. Particle swarm optimization as one of the most popular nature-inspired metaheuristic optimization algorithms, is carried out for assigning relative weights to each DRASTIC parameter in order to improve objectivity and robustness of vulnerability index. The performance of generic and optimized DRASTIC indices is validated based on nitrate concentration in monitoring wells as accepted criteria in agricultural regions, using the Area under the Receiver Operating Characteristic (ROC) Curve (AUC). Results indicated that optimization of weights considerably improved the accuracy of vulnerability index from 0.58 for generic DRASTIC index to 0.75 for DRASTIC-PSO index. The proposed optimization process provides a feasible framework from integrating hydrogeological characteristics of the aquifer and major contamination load in the study area, thereby it can be versatile to be applied in different case studies.

Keywords: Groundwater, Vulnerability mapping, Optimized DRASTIC, Particle swarm optimization (PSO), GIS

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Session Classification : Parallel

Track Classification : Topic 8 - Groundwater quality and pollution processes
Prediction of Groundwater Inflow Rates to an open Pit Mine in Eastern Turkey

Friday, 27 September 2019 09:55 (15)

Prediction of groundwater inflow rates to an open pit is an important issue because unexpected flows can cause safety and environmental problems. This paper presents groundwater inflow rates to an open pit mine developed in metasediment and diorite in Eastern Turkey. Representative hydrogeological conceptual model was developed based on data collected from field studies and subsequently it was transferred to a two-dimensional numerical model through SEEP/W of GeoStudio. After construction of model grid and assignment of hydraulic properties along a selected critical cross section, calibration of the model was conducted under steady-state conditions by trial and error. The root mean square error was calculated as 6.54 meter, 93.56 kPa and 9.57 meter for total hydraulic head, pore water pressure and pressure head values, respectively. The steady state calibration was followed by transient analyses for twenty years to confirm the simulated steady-state values. Results show that transient run in the long term reached a steady-state condition which was not significantly different than the generated steady-state solution, thus confirming the adequacy of the model for estimation of groundwater inflow rates. The groundwater inflow rates were predicted by running the model under transient conditions over a two-month period during which the material from the open pit has been removed. The results of each phase represented initial conditions for the subsequent phases. The results for a one-year simulation show a sudden increase in the inflow rates through the pit bottom when its elevation is lowered by 50 meters. As the pit bottom deepens, groundwater inflow through east and west slopes also increased. Hence, increase in groundwater inflow from east and east slopes indicates that a drainage scheme must be designed for both slopes.

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Session Classification : Parallel

Track Classification : Topic 5 - Tools, methods and models to study groundwater
The Urban Water Cycle - SuDS as a measure for preservation and prevention; example from Bergen, Norway

Tuesday, 24 September 2019 11:30 (15)

Guri Venvik, Ane Bang-Kittilsen, John Dehls & Floris C. Boogaard
The infiltration systems at Bryggen in Bergen, Western Norway, were built to protect and preserve the UNESCO World Heritage Site Bryggen Wharf and its cultural layers below. This location is an example where Sustainable Urban Drainage Systems (SuDS) have been implemented to collect, infiltrate and store surface water. Rainwatergardens, swales and permeable pavement have been implemented to restore the groundwater level and increase soil moisture in order to preserve the cultural, organic layers (Rytter & Schonhowd, 2015).
Bergen city centre is prone to both subsidence and flooding. With a predicted increase in precipitation due to climate change a higher proportion of rainfall becomes surface runoff, which results in increased peak flood discharges. In addition, sea level rise and increasing storm surges are predicted which causes coastal flooding.
The hydraulic infiltration capacity of the rain garden has been tested with a full-scale infiltration test with the response on the groundwater levels monitored in wells. Result show that infiltration capacity meets the international guidelines requirement of 100 -300 mm/h, with 1600 mm/h for the large and 510 mm/h for the smaller under saturated conditions. An immediate response of the full-scale infiltration test is shown in the wells located closest to the infiltration point, with a delayed response in the wells further away. Results show that he infiltration capacity of the rain garden exceeds the amount of available surface water and the groundwater level would, in dry periods, benefit from more water, to preserve cultural layers. Therefore, the connected runoff area can be extended to encompass the total catchment area. This can be used for improving existing and future urban drainage and water quality models used to assess the performance of SuDS, where Bryggen is a Best Management Practice (Venvik & Boogaard, submitted).
In a parallel study two different analysis methods are tested using ArcGIS tools to develop risk assessment maps for areas most prone to the combination of both flooding and subsidence. Applying user-centred principles, this work focuses on methods for maps as a support tool to identify areas where mitigation of subsidence and adaptation for surface water management will be most efficient, since there is a link between areas that suffer from surpluses or shortages of water and subsidence in urban areas, for further implementations of measures. The results indicated that one of the methods give more significant results compared to the other method. Such method will be a helpful tool for decision-makers when prioritizing areas to implement measures such as Sustainable urban Drainage Systems (Venvik et al., submitted).
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**Session Classification**: Parallel

**Track Classification**: Topic 10 - Urban groundwater
Protecting a freshwater lens against sea level rise: a field experiment

Monday, 23 September 2019 12:15 (15)

In the southwestern part of The Netherlands, a 75-ha-agricultural area called Perkpolder was transformed into a tidal area to restore a salt marsh ecosystem. In June 2015 the open connection to the sea was realized. This transformation created an average water level increase of about 1.5m and can be seen as a local sea level rise of 1.5m and may have significant effects on the groundwater system of the adjacent lying agricultural area. Below this agricultural area, a 20-meter-thick freshwater lens surrounded by saline groundwater provides the farmers fresh groundwater for irrigating their crops. It is expected that due to this local sea level rise, hydraulic heads increase resulting in shrinkage and eventually disappearance of this precious freshwater lens.

To protect this lens, a self-flowing seepage system called SeepCat was designed and installed to compensate effects resulting from this local sea level rise. The freshwater lens is one of the Badon-Ghyben-Herzberg type and will shrink when hydraulic heads below the lens increase. The task of the SeepCat-system is to release the increased pressure in the aquifer. The SeepCat-system consists of 61 vertical seepage wells with 5-10m long screens, installed in the aquifer at 15m depth, over a total length of 1100 m. Since the hydraulic heads in the aquifer are higher than the surface water level, the seepage wells are artesian and self-flowing. The extracted saline seepage water is discharged into a canal and pumped into the sea.

Since 2010, hydraulic heads (30 locations) and the fresh-salt interface (15 location) are being monitored to capture the reference situation, to determine effects resulting from the development of the new tidal area and to monitor the functioning of the SeepCat-system. Time series analysis was applied to quantify the effects. From the head measurements it is concluded that the seepage system is functioning well and fully compensate the effects of the local sea level rise. No changes in the fresh-salt interface have been detected yet. However, these processes occur at a much larger time scale since salt transport is involved. To determine these long-term effects, the numerical groundwater model SEAWAT was applied. The model results show that SeepCat is successful in mitigating the effects of this local sea level rise and without SeepCat, half of the precious freshwater lens would disappear after 100 years.

The Perkpolder case serves as a field laboratory where effects of sea level rise are measured and mitigation measures for sea level rise are tested. Since the system is technically and geohydrologically working well, it could also be applied in other coastal areas, like small ocean islands. The SeepCat-system could help to protect their vulnerable freshwater resources which are seriously threatened by the expected future sea level rise.

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Session Classification : Parallel

Track Classification : Topic 1 - Groundwater assessment and management
The effect of multi-step adsorption isotherms on the solute transport in porous media

Retardation due to adsorption may be an important factor in the fate and transport of contaminants in porous media. Reversible adsorption is generally described by isotherm functions giving the relationship between the concentrations in dissolved and in adsorbed phases. Several authors defined such parametric functions, the most widely used being the linear, the Freundlich and the Langmuir isotherms, which are also implemented in many solute transport simulation software. Some substances however exhibit a multi-step adsorption isotherm, mostly for organic compounds or organic adsorbents, as indicated by a few papers.

The isotherm function defined by Czinkota et al. (2002) introduces a limit concentration above which new adsorption mechanism starts to take place. By summing up simple nonlinear isotherms in which the limit concentrations are set, isotherms including several steps may be described. One important feature of these multi-step isotherms is that their first derivative is not a monotonic function, hence the retardation factor may have several peaks if plotted against the solute concentration.

The effect of multi-step isotherms have been studied numerically with a modified version of the MT3DMS software. For this reason a general sorption isotherm (GSI) package have been developed which extends the functionality of the reaction (RCT) package with the ability to define arbitrary isotherms.

Adsorption described by multi-step isotherms may develop a specific concentration distribution during advective transport. As the retardation factor may have several peaks, the position of which is determined by the limit concentrations, several solute concentration fronts may develop, forming a step-wise concentration distribution.

The most evident parameters affecting the concentration distribution are the limit concentrations as they determine the "height" of the plateaus. Concentrations higher than the limit are characterized by sharply increased retardation which will delay their propagation. Other relations may be described depending on the type of isotherm function being used to describe the multi-step isotherm. When using Langmuir parameters, the propagation of concentration fronts seems to be determined by the adsorption capacity and the Langmuir constant.

The concentration distribution developed by multi-step isotherms may be altered by other transport processes like dispersion/diffusion or reactions. Their effect is to be expected as usual. The diffusion may be increased by the high concentration gradient along the concentration fronts.

Session Classification: Parallel

Track Classification: Topic 5 - Tools, methods and models to study groundwater
In March 2019, educational science activities were held in different Spanish regions in order to highlight the importance of groundwater resources, known as “Hidrogeodia”. This initiative is an excellent dissemination tool that promotes the knowledge and the importance of groundwater, the history-cultural sites and the heritage elements of great hydrogeological interest associated with them.

The Hidrogeodia has been an initiative of the Spanish Group of the International Association of Hydrogeologist (IAH-GE) in collaboration with many different scientific organizations, universities and Spanish public research organizations. The activity consists of a free hydrogeological field trips in each region, open to the general public and guided by hydrogeologists. The Hidrogeodia is celebrated on behalf of World Water Day (22 March), on weekends before or after this date. This year 2019, the third Hidrogeodia edition has been very successful with nearly 1400 people attendees (organizers, volunteers and assistants included) in all the activities. In addition, to the 8 pioneering regions of the Hidrogeodia 2017 (A Coruña, Alicante, Almería, Barcelona, Granada, Madrid, Málaga and Murcia), another 11 Spanish provinces joined this initiative in 2019 (Albacete, Asturias, Burgos, Cáceres, Ciudad Real, Huelva, Jaén, Segovia, Sevilla, Tenerife, Valencia and Zaragoza), and Andorra. Thus, the great interest shown by the participants and the involvement of the different collaborating entities has been demonstrated. The diffusion of the event by the IAH-GE through the different media (Web, Instagram, Facebook, collaborating entities websites, etc.) has significantly contributed to the great success of the Hidrogeodia 2019.

From this moment, the IAH-GE is starting to work on the Hidrogeodia 2020, trying to involve more institutions and with the aim that this experience of dissemination of the hydrogeology can be extended soon throughout the national territory, as well as to other neighboring countries.

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Session Classification :  Poster with refreshments

Track Classification :  Topic 6 - Groundwater, wetlands and natural heritage
Present and future potential groundwater recharge from precipitations over France

Quantifying the future renewable groundwater resource is a key point for water managers in the context of climate change. A method to estimate potential groundwater recharge from precipitation has been developed and applied over France for that purpose.

A gridded water budget model was developed to compute the effective rainfall with a spatial resolution of 8x8 km, at a daily time step. Three different water budget methods were included to assess uncertainties associated to the model design. We then elaborated a method to split the effective rainfall between runoff and infiltration, relying on a GIS built parameter called IDPR. This distributed parameter relates to the drainage density and hydrological network. We calculated the river baseflow index (BFI) using the Wallingford method over more than 350 French monitored river basins. Assuming that BFI represents the groundwater contribution to surface flow in a river basin, it can be used to estimate the mean infiltration coefficient over the considered basin. A relationship between the calculated BFI and IDPR spatial average calculated over the 350 river basins was established. It thus allowed estimating a spatially distributed infiltration ratio. The potential annual recharge was defined as the product of this ratio with the effective rainfall previously calculated. Hence, present and future recharge maps for France were generated to assess the impact of different climate change scenarios.

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Session Classification :  Parallel

Track Classification :  Topic 2 - Groundwater and climate change
Typology of karst aquifers in Europe: a review – GeoERA RESOURCE project, CHAKA work package

Thursday, 26 September 2019 11:30 (15)

Although karst aquifers represent a widespread groundwater resource in Europe, there is no unified classification and each country has adopted its own typology, taking into account the characteristics of their own karst aquifers. The main objective of the CHAKA (CHAlk and KArst) work package, part of the GeoERA RESOURCE project (http://geoera.eu/projects/resource9/), is to achieve a joint classification typology that should be applicable to a large spectrum of karstic environments, and to associate it to recommendations regarding aquifer management (aquifer protection, monitoring strategies, exploitation, etc.). This presentation describes the current state of the art, in the sense of reviewing the existing methods/approaches used in the different partner countries to classify karst aquifers taking into account the responses from time series analysis. The existing approaches of carbonate aquifer characterization are studied and the differences and complementarity of the different approaches are discussed. The potential gaps are also identified.

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Session Classification: Parallel

Track Classification: Topic 7 - Karst Hydrogeology
Identification of the denitrifier microbial communities at the water-sediment interface in a discharge type saline lake

Tuesday, 24 September 2019 16:00 (60)

Industrial, agricultural, and domestic activities originate several environmental aftermaths. Among them, the massive increase in undesirable inorganic nitrogen (N) loads within the aquatic environment causes serious threat to surface waters. Denitrification is a crucial part of N transformation, linking organic matter oxidation to benign dinitrogen molecule (N2) production from nitrate. In this sense, hypersaline environments provide unique conditions where redox processes mediated by microorganisms adapted to extreme conditions lead to nitrogen turnover. This is the case of the hypersaline Pétrola Lake (SE Spain), that constitutes the discharge zone of an endorheic basin of 42 km2. It is under the influence of various anthropic activities (agricultural and livestock activities, wastewater discharge without prior treatment), originating the continuous loading of different pollutants (i.e. pesticides, nitrate.). Hydrogeologically, surface waters are connected to groundwater throughout a complex density driven flow (DDF). One of the effects of this DDF is the transport of solutes to deep aquifer zones, playing an important role in the recycling of nutrients, such as N, and the distribution of anthropogenic and natural-derived dissolved organic carbon. Prior to the incorporation in the DDF, some of the transformations of N species take place in named sediment-water interface in which microbial activity promotes different redox processes such as denitrification. The objective of this work is the evaluation of the denitrifier communities of the organic-rich sediments of the hypersaline Pétrola Lake, which may be responsible for the attenuation processes of contaminants and N recycling.

To evaluate the presence of denitrifier communities, sediments were collected at 7 different points from the Pétrola Lake according to the different pollutant inputs (agricultural, livestock, wastewater). The bacterial genomic DNA was extracted from these samples and subjected to a metagenomic analysis by high-throughput amplification and sequencing of the V3-V4 region of the 16S rRNA gene. The results obtained were scanned to evaluate the presence of bacteria related to denitrification processes.

Pétrola Lake sediments showed a high diversity in extremophiles. Some of them are related to the occurrence of N recycling, like bacteria from the family Ectothiorhodospiraceae, which produce the complete autotrophic denitrification under halophilic conditions. Within this family, it is especially remarkable the presence of bacteria from the genus Thioalkalivibrio, accounting about 7% of the total bacteria identified in such sediments. In addition, other microorganisms like some members of the Halomonadaceae family, present at all sampling points, can grow anaerobically using nitrate as electron acceptor and converting it into nitrite. Other families related to N cycle are also present in the sediments of Pétrola Lake, like Pseudomonadaceae or Nitrospinaeaceae, although in a minor proportion. This study contributes to our understanding of halophilic microbial communities in denitrification processes.

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**Session Classification:** Poster with refreshments

**Track Classification:** Topic 8 - Groundwater quality and pollution processes
Hydrodynamic modeling of Ranney wells in Hungary

Tuesday, 24 September 2019 16:00 (60)

The riverbank filtration systems are playing a major role in water supply of Hungary. The 35–40% of Hungary’s water supply and about 75% of our perspective water sources rely on these riverbank filtrated water sources.

In our work we deal with the seepage conditions of horizontal wells. Nowadays this well type, developed by Leo Ranney, is the most used water extract equipment for riverbank filtrated systems all over the world. The advantage of these well types that with the horizontal placement of the screens, we can increase the effective screen area, and we can provide bigger flowrate than the vertical wells in these geological situations. As we can experience, extreme water levels can be formed in our rivers, which can have the effect on the seepage conditions, and water treatment mechanism of riverbank filtrated systems. The MODFLOW software’s Multi Node Well 2 (MNW2) module can handle the hydrodynamic calculations of horizontal, and angled wells. Our aim is to test the suitability of MODFLOW software package’s MNW2 module, for hydraulic modeling of Ranney wells. As a first step we would like to calibrate the MNW2 module, and for this we use other independent calculation methods. After the calibration we would like to use this module to determine real seepage conditions in existing riverbank filtrated systems.

With the help of hydraulic simulation, considering the extreme water levels of the rivers, we can optimize the operation of these type of horizontal wells, and we can react on extreme hydrological conditions in water supply.

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Session Classification: Poster with refreshments

Track Classification: Topic 5 - Tools, methods and models to study groundwater
Underground hard coal mine flooding control as a factor for limiting methane emissions to the atmosphere and for enabling its utilisation

Tuesday, 24 September 2019 16:00 (60)

Thus far, the condition of hard coal mining in the USCB reflects the general global trends, which prefer to limit the extraction of hard coal. Therefore new and unmined deposits are practically not opened out, whereas the extraction in active mines is either limited or nearing conclusion. Processes related to the decommissioning of mines and their total or partial flooding are currently widespread both in Czechia as well as in Poland. On the one hand, this process influences the ejection of methane towards the surface from the lowest-situated and typically methane-rich coal beds and workings, but on the other hand it may limit the desorption of methane and its long-term emission to the atmosphere through the restoration of static water resources and the renewed water saturation of the rock mass. Therefore the authors have concluded that the course of the mine flooding process should be forecast with the greatest precision. The rate of working flooding and methane ejection towards the surface can be regulated by controlling the drainage process conducted during mine flooding. It is beneficial to limit the rate of mine flooding in order to prevent the compression and non-concentrated outflows of mine gases with intensities that may result in significant methane emissions and general hazards on the surface. Yet on the other hand, limiting the rate at which water levels increase in the gobs will result in the removal of the majority of gas from post-mining caverns, and will simultaneously limit their emission and desorption from coal beds through the water saturation of the rock mass and the blocking of the routes of gas migration. This is significant in a hydrogeologically unconfined area where partial flooding of only the deep and methane-rich coal beds can be considered beneficial due to the limitation of the influence on climate change. As for mines in hydrogeologically confined areas, in order for methane emissions, including uncontrolled emissions, to cease completely, the flooding would have to concern the entire coal-bearing formation in the area of the mine. This often constitutes a significant limitation to the use of deposits adjacent to the flooded mine. On the other hand, maintaining the water table and the partial flooding of a methane-rich mine in the hydrogeologically confined area enables the planning of the controlled capture of methane and its utilisation. This also makes it possible to avoid uncontrolled releases of methane to the surface and the atmosphere, and allows the selection of the means for methane capture during the degasification processes of deposits, which is certainly beneficial with regard to climate change and the safety of adjacent mining activities.

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**Session Classification**: Poster with refreshments

**Track Classification**: Topic 5 - Tools, methods and models to study groundwater
Investigation of industrial waste heat storage in porous media

Monday, 23 September 2019 16:00 (60)

The preferable geothermal conditions of Hungary give good opportunities to produce geothermal energy. Besides this well-known fact, Hungary also concentrates on the investigation of industrial waste heat underground storage possibilities. In Northern-Hungary there are many industrial areas with high amount of waste heat emission. Nowadays, most of the unused heat is released into surface waters, and there is no reutilization activity. On the other hand, several heat storage technologies are known, which use geologic formations as a storage volume. During our investigations, we outlined different heat storage possibilities of shallow porous formations using real data. We decided that one of our test sites could be in Tiszaújváros, because this is an industrial area, which produce a high amount of waste heat, and on the other hand, we have detailed geological information about this test site.

The presented research analyses the use of hot wastewater coming from the cooling systems of huge enterprises. The industrial waste heat can be stored in sedimentary aquifer thermal storage systems (ATES), and later it can be used as a heat source in heating systems during wintertime. The aim of the conducted research is to assess the heat storage capacity of the underground sediment formations at Tiszaújváros industrial town through three-dimensional groundwater flow and heat transport simulations, as well as to identify the ideal parameters of storage using different scenarios. The simulations have been developed using MT3DS as heat transport simulator. We developed a basic simplified model, with 700 m total thickness, and a 100 m thick ATES layer in it. In this simplified model four different types of well locations were investigated. In the models we used injection wells which inject hot water in the sedimentary target formation, and we used production a well or wells to pump the stored hot water to the surface. We calculated energetic efficiencies for each basic situation. Based on the obtained results, it is possible to realize a well-working and reliable underground heat storage system.

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Session Classification : Poster with refreshments
Track Classification: Topic 1 - Groundwater assessment and management
Impact of historic and future climate on spring recharge and discharge based on an integrated numerical modelling approach: Application on a snow-governed semi-arid karst catchment area

Thursday, 26 September 2019 11:45 (15)

Flow in a karst system in Lebanon (Important water supply source; Assal Spring; discharge 0.2–2.5 m³/s yearly volume of 22–30 Mm³), which is dominated by snow and semi-arid conditions, was simulated using an integrated numerical model (Mike She, 2016). The calibrated model (Nash–Sutcliffe coefficient of 0.77) is based on high resolution input data (2014–2017) and detailed catchment characterization. A sensitivity analysis of individual climatic parameters shows that spring hydrograph characteristics are most sensitive to temperature.

A forward simulation using the IPS_cm5 model with the RCP6.0 scenario for future climate change (Global Climate Models GCM; daily downscaled bias and altitude corrected time series for Lebanon 2020–2099) unravel that precipitation, recharge, and discharge have moderate to highly significant decreasing trends with time over the 21st century. Moreover, recession flowrates are expected to drop drastically starting in the year 2070 to 1 l/s with shortage periods reaching up to six months. The latter is due to a temperature rise of +1.5–2.5 °C and subsequent shrinking of snow cover by almost 100% (e.g., 2073–2074). Furthermore, this is accompanied by a decline in annual spring volume by 73% with respect to the current status, with real evapotranspiration consisting of up to 50% from total water budget (currently around 12–17% in 2014–2017). Moreover, decreasing snow accumulation and a more prominent flushing of precipitation event waters into fast preferential pathways will lead to peak spring discharges. This study allows decision makers to implement best informed practices for future water resources management especially for karst systems under semi-arid conditions in the regions.

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Session Classification: Parallel

Track Classification: Topic 7 - Karst Hydrogeology
Calibration of a semi-distributed lumped model of a karst system using time series data analysis: the example of the Qachqouch karst spring (Lebanon)

Thursday, 26 September 2019 12:15 (15)

Flow in complex karst aquifers is challenging to conceptualize, especially in poorly investigated areas, in semi-arid climates and under changing climate conditions. Based on more than three years of high resolution continuous monitoring, a semi-distributed lumped model (MikeShe 2016) was calibrated and validated for the Qachqouch karst spring, North of Beirut (Lebanon). Time series analyses and decomposition of spring hydrographs showed that the system has a high regulatory behaviour with a considerable storage capacity providing a stable flow depletion (minimum flow of 0.2 m$^3$/s) during the entire dry season, with flow rates reaching more than 10 m$^3$/s during the wet season, similarly to other karst aquifers in the region. Acquiring this detailed understanding of the hydrodynamic of the system allowed refining and validating the developed semi-distributed conceptual model of three linear reservoirs used to reproduce the combination of the contribution of the different flow components of the systems, cause of the high contrasts of flow rates in the spring discharge. The obtained satisfactory precision (Nash-Sutcliff index 0.7) is due to the use of sensitive parameters for the model calibration deduced from the performed time series analyses, such as the number of reservoirs and their time constant. Climate change conditions (+1 to +3°C warming, -10 to -30% less precipitation annually, and increased intensity) were applied to an average climatic year to produce scenarios of expected spring flow responses. The comparison of future simulations to the baseline scenario showed that Qachqouch karst aquifer tends to be sensitive mostly to rainfall decrease, leading to more important recessions with flow rates decreased by 34% and duration dry periods approximately one month longer. Since the influence of snow on the spring flow rate revealed to be minimal, a warming effect on climate exacerbates to a relative lesser extent the spring conditions than loss in precipitation. Although the model shows that increasing daily rain intensity creates higher flood flow that could lead to longer recessions, thus slightly reducing the length of the low flow period in comparison with the baseline, the real impact of high intensity precipitation events is uncertain. This work shows that calibrating a semi-distributed lumped model using time series analyses seems to be an efficient approach to enhance the quality of simulations for complex karst aquifers. This is expected to be especially true for karst aquifers where subsurface characterization is very difficult, thus providing a more detailed model for a better long-term sustainable water management.

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Session Classification : Parallel

Track Classification : Topic 7 - Karst Hydrogeology
Understanding streamflow reductions using a distributed rainfall/runoff model and remote sensing for the Verlorenvlei estuarine lake, west coast, South Africa

Climate change is driving increased variability in precipitation patterns across much of southern Africa, making it challenging to model catchment-scale water dynamics using historical data. This has implications for effective water management particularly in water scarce areas which have competing users. Agriculture is an important water user which lacks detailed records of surface and water abstraction, making it difficult for hydrological models to replicate catchment water balances required for effective management. This study takes a fully distributed hydrological model (J2000), which was initially developed to model virgin streamflow, and incorporates remote sensing evapotranspiration to understand the impact of irrigation on both streamflow and baseflow. The model was developed for the RAMSAR listed Verlorenvlei estuarine lake, South Africa. Recent drought in the region has shown that understanding low-flow conditions is critical to the long-term ecological sustainability of the lake, but the lake catchment is also an important agricultural region that competes for scarce water resources. The J2000 model developed to model recharge and aquifer baseflow through a coupled approach and has here been modified to incorporate remote sensing estimates of evapotranspiration to quantify streamflow reduction. The irrigation package of the J2000 was firstly modified to satisfy the remote sensed ET demand using the modelled streamflow during the wet months of the year. During low flow conditions (dry months), the irrigation package was instructed to utilise stored groundwater from either the primary or secondary aquifer or both based on the abstraction position within the sub-catchment. The results of the study show that the streamflow reductions are significant in this sub-catchment and that if agricultural expansion continues there will not be enough water to support the high biodiversity levels of the Verlorenvlei. While the impact of climate change on rainfall in the region has not been incorporated into the model structure as of yet, it is expected that there will be a reduction in rainfall into the future, which will further impact the systems’ ability to handle sustained periods of low flow conditions. The methodology used in this study can be transferred to other semi-arid catchments which lack sufficient streamflow estimates to guide effective water management and limit the over allocation of water resources for socio-economic development and poverty alleviation.

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**Session Classification**: Poster with refreshments

**Track Classification**: Topic 6 - Groundwater, wetlands and natural heritage
Determining the apparent age of old groundwater of the deep-lying Ohangwena aquifer in the Kalahari Basin, Northern Namibia

Tuesday, 24 September 2019 16:00 (60)

In arid areas, underground reserves of water from deep sedimentary aquifers containing old groundwater, probably recharged thousands of years ago, have been recognized as a valuable additional source of drinking water. The recently discovered, deep-seated groundwater reservoir of the Ohangwena (KOH-2) aquifer forms part of the north-south trending Cubango Megafan deposited in the border area between Angola and Namibia. It has been explored at depths between about 250 to 350 meters in northern Namibia in an area between 17.3 and 18 degrees southern latitude and 16 and 17.3 degrees eastern longitude. The amount of stored groundwater in the KOH-2 aquifer on Namibian territory is conservatively estimated at 20 billion cubic meters. A proper understanding of the origin, history and dynamics of the presumably very old groundwaters found in the KOH-2 aquifer is a key for the assessment of the reliability and potential of this aquifer as a strategic resource for supply of drinking water into the future.

The objective of the study is to determine the apparent age of the groundwater in the KOH-2 and to improve the understanding of the hydrogeological setup of the multilayered aquifer system developed within the Cubango Megafan. An overall aim is to investigate the use of long-lived radionuclides, particularly 4He and 81Kr, to assess their reliability as age tracers of old groundwaters. The use of the radioactive 81Kr and 36Cl isotopes, with a half-life of 229,000 and 301,000 years, respectively, allows an estimation of recharge over timescales ranging from 50,000 to several hundred thousand years, a range beyond the reach of radiocarbon. Concentrations of radiogenic 4He derived from the decay of uranium and thorium in deep groundwater may be used as a qualitative or semi-quantitative age proxy.

A comprehensive sampling campaign was carried out during March 2019, which comprised eight deep boreholes of the KOH-2 aquifer. The apparent groundwater ages will be determined from gas and water samples using radionuclide dating techniques comprising 85Kr/81Kr, 4He, 14C and 36Cl. In order to extract bulk gas from groundwater, a new field-gas extraction device was developed comprising a commercially available hydrophobic semipermeable membrane contactor, a membrane vacuum pump, a compressor and a memograph to record gas pressure and water flows. For each well, the gas was collected in a 12.3 L evacuated stainless steel cylinder and compressed to 1.5 bar. Krypton separation from the bulk gas acquired in the field is currently performed at the University of Bern, Switzerland. Krypton abundances are determined using atom trap trace analyses (ATTA) by the National Laboratory Argonne, U.S.

The research is carried out as under the international Coordinated Research Programme “Use of Long-lived Radionuclides for Dating Very Old Groundwaters” (F33023) initiated and coordinated by the International Atomic Energy Agency (IAEA).

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Session Classification: Poster with refreshments

Track Classification: Topic 5 - Tools, methods and models to study groundwater
Drivers of changes in Austrian groundwater levels – climate vs. water use

Groundwater is an important resource for public, industrial, and agricultural water use. Climate change alters the hydrological cycle and thus also the replenishment of groundwater resources by infiltrating precipitation or surface waters. In Austria, renewable freshwater resources overall exceed by far water use, but in the eastern part of the country considerably lower precipitation and thus lower groundwater recharge prevails. Warming in the Alpine region since the late 19th century was twice as high as the northern hemispheric and global average. Thus, potential impacts of climate change on Austria’s water resources warrant attention. Future changes in water or land use (which may or may not be induced by climate change) can aggravate or mitigate adverse climate change impacts on groundwater. To improve our understanding and identify potential drivers of long-term trends and short-term responses of groundwater levels, we analyze standardized time series of groundwater levels, stream stages, and precipitation in Austria. As we have recently shown (Haas and Birk, J. Hydrol.: Reg. Stud., 2019) countrywide and regional averages of groundwater levels trend downwards until the 1980s, from whereon they recover. As compared to the distinct falling trend, the subsequent rise is less pronounced. Precipitation follows this track, but the downward trend is less severe. River stages lack data for the downward trending period, but follow the upward trend too. We hypothesize that the increasing water use before the 1980s accounts for the discrepancy between average precipitation and average groundwater level in this period, especially since Austria meets its water demand mostly from groundwater and the observation wells cluster around areas with high water demand. Although Austria has a diverse and differing geography, the observed trends hold for almost all regional subsets. However, since most groundwater observation wells follow human use, large parts of the country (mainly the mountainous regions) lack long-term groundwater data. Thus, the findings of this work are representative for Austria’s populated lowland and valleys rather than for the Alpine peaks and ranges.

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Session Classification : Parallel

Track Classification : Topic 2 - Groundwater and climate change
Developing a hydrostratigraphic classification system for South Africa.

Monday, 23 September 2019 12:00 (15)

Description of hydrogeological systems traditionally relies on a few factors, such as porosity, rock type and the hydraulic parameters, transmissivity and storativity. Some studies include terms for rainfall, recharge and aquifer boundaries. Inconsistency in reporting makes it hard to compare hydrogeological units and reliance on hydraulic parameters fails to consider the assumptions in hydraulic testing theory, which are often not met.

South Africa has a stratigraphic record spanning 3.5Ga, including world class examples of Archaean granite-greenstones, Archaean volcano-sedimentary sequences, Proterozoic metamorphic belts, the world’s largest layered igneous complex, the Pan-African orogeny, a Permo-Triassic fold belt, a Pan-African continental foreland basin, a continental flood basalt, and extensive inland and coastal Mesozoic to Cenozoic deposits. The landscape ranges from sea level to 3500m elevation, with plains, fold mountains, the Southern-African Great Escarpment, canyons, inselbergs and other landforms. The climate ranges from Mediterranean near Cape Town with snow on the mountains in winter, through sub-tropical to tropical, with seasonal monsoon style thunderstorms or perennial advective rainfall, to desert. Annual rainfall ranges from zero often in the deserts of the north-west to over 3m in the Cape Mountains. Temperatures range from winter minimums of <0 C to summer maximums of >40 C.

Hydrogeologists working in South Africa face this complexity when describing a hydrostratigraphic unit. Multilinguilism (11 official languages) and developing world constraints on time, money and education provide additional challenges. This paper refreshes knowledge of technical terms, promotes correct use of this terminology, highlights similarities and differences between hydrogeological units countrywide, and suggests the level of information needed to make management decisions. Terms such as soil, regolith and saprolite are defined; grading and sorting and their influence on porosity are explained; representative elementary volume, especially in context of fracture networks is also explained. The distribution and flow of water is dealt with, especially complex vadoze zone flows such as imbibition, interflow and percolation. The above factors are integrated by relating these to 5 fundamental drivers: geology, geomorphology, climate, water state and human effects. The first three of these are seen as earth system constants, unchanging on a human time scale, whereas the last two are the temporal behaviours that modify the earth system condition.

A fixed hydrostratigraphic classification system is not proposed, as the complexity and level of uncertainty precludes this. However, 10 examples of hydrogeological settings are given, spanning the diversity found in South Africa, and applying the terminology presented. This shows how reporting of typical hydrogeological investigation results (hydraulic aquifer tests, water quality analyses) needs to be augmented with information from the 5 fundamental knowledge areas to achieve a more meaningful description of the hydrogeological units, creating more consistent descriptions and ultimately allowing hydrostratigraphic classification countrywide.

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Session Classification: Parallel

Track Classification: Topic 1 - Groundwater assessment and management
Climate effects on intra-annual groundwater level fluctuations in Fennoscandia

Climate strongly influences the regional hydrology. However, the relationship between climate-specific seasonal fluctuations and groundwater dynamics is not well defined for Fennoscandia. For the period 1980-2016, the climate in Sweden and Finland is classified as subarctic, with the most southern parts of Sweden classified as humid continental climate (Kottek et al., 2006; Beck et al., 2018). These climate zones have a winter season heavily affecting the water balance. Large quantities of precipitation accumulate as snow in the cold months and is released during a melting period in spring. This distinctive cycle affects the groundwater level. Annual maxima occur during periods characterised by low evapotranspiration (ET) and snowmelt. Groundwater level minima coincide with high ET and precipitation events occurring at negative temperatures (snowfall). Kottek et al. (2006) predict the subarctic climate zone to shift northwards between the classification periods 1951-1975 and 2001-2025. The climate zones are expected to shift more dramatically in space during the current century, altering the local winter season furthermore (Beck et al., 2018). How this affects the regional hydrology is important for mitigation efforts and management, since high and low water tables occur in conjunction with incidence of water scarcity, floods, and hydrological droughts.

This research focusses on the identification of characteristics and driving mechanisms of intra-annual groundwater level fluctuations in Sweden and Finland. Mean timing and duration of gaining (positive water budget) and losing (negative water budget) periods are identified for several groundwater observation sites. The time series consist of biweekly measurements. The time series for two 5-year periods (1980-1984 – "past", 2006-2010 – "present") are correlated to modelled (temperature and precipitation-based) snowmelt, rainy and high ET periods to identify driving mechanism. Changes in the dynamic behaviour between both periods are quantified by a statistical evaluation of the time series. Spatiotemporal analysis show how the climate zones impact local water table dynamics, and how the climate zone shift affects change in groundwater level fluctuations.

References:
Multidisciplinary approach to study the landfill leachate impact on groundwater hydrogeochemistry in aquitard and aquiclude

Tuesday, 24 September 2019 11:15 (15)

The interaction between the leachate and the environmental media, in addition to spreading toxic compound in groundwater, leads to several hydrogeochemical and biological changes that, in turn, affect the natural conditions of aquifers. These changes also involve compounds that are generally considered slightly or not polluting, such as the major ions (Na, K, Ca, Mg, Cl, SO4, HCO3 + CO3), notwithstanding the Concentration Limits of Contamination (CLC) required by the current environmental legislation.

In this general framework, the main objective of this research is to get a deeper insight into these processes, related to the leachate/groundwater interaction, in a landfill site where the CLC exceedances are limited.

The selected study areas is a landfills located in Central Italy, within the scarcely permeable plio-pleistocenic clayey deposits, that present a superficial alteration (silty-clayey lithologies).

The hydrogeological characterization has been performed deepening different features: (1) the geological features have been described in detail, even with respect to the landfill volume, by means of geognostic boreholes; (2) the groundwater flow has been investigated by the hydraulic head time-series analysis and the permeability tests performed in site; (3) the chemical analyses of surface water, groundwater and leachate, analyzed as water (i.e. the same units and detection limits), have been compared to assess the contamination extent and to interpret the changes related to leachate leaks in the aquifer.

The preliminary results highlight that the clayey bedrock alteration (up to 15 m thick) favors, where the landfill is unlined, the mixing between leachate and groundwater that flows toward the stream. The hydraulic conductivity of this alteration is an order of magnitude higher (~10^-8 m/s) than the clayey bedrock one (~10^-9 m/s).

The contaminated groundwater, in addition to showing CLC exceedances related to some organochlorinated solvents, are characterized by high concentrations of redox-sensitive ions (e.g. Fe e Mn), due to the anoxic conditions caused by the dissolved organic matter. Furthermore, the contaminated groundwater is enriched in ions Na, K, Cl, SO4, HCO3 + CO3 and depleted in in Ca and Mg respect to the natural groundwater. This effect can be considered a combination of intermediate redox conditions, that bring to the S species oxidation, and mixing and/or cation exchange, attributable to the clayey minerals in the aquifer.

The multidisciplinary approach has enabled to clarify a complex environmental problem. In particular, the comparison between the chemical analyses of the landfill leachate, analyzed as water, and the and natural and contaminated groundwater has allowed to get a deeper insight into the hydrogeochemical processes that change the groundwater chemistry when a landfill leachate contamination occurs.

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**Session Classification**: Parallel

**Track Classification**: Topic 8 - Groundwater quality and pollution processes
Pumping response and sustainable well yield of some hard-rock aquifers

Monday, 23 September 2019 11:15

The issue of sustainable yield of some wells drilled in hard rocks of the Mediterranean Region was examined. The objective of the study was to verify which information may be obtained from the results of pumping tests in order to define the long-term well functioning. These aquifers might play a strategic role in drinking and irrigation water supplies for the Mediterranean Region in a near future.

Data analyzed concern results of pumping tests performed in three areas with similar climate conditions, which differ in hard-rock type (intrusive, effusive and metamorphic rocks). The pumping data were interpreted with analytical techniques and commercial software. This allowed to recognize three main drawdown trends, coherent with three hydrogeological settings: i) delayed response coherent with the presence of double porosity; ii) rapid increase of drawdown coherent with the presence of a barrier boundary, iii) stabilization of the water level over time coherent with the presence of a recharge boundary. On the basis of the identified trends and hydraulic parameters, different pumping scenarios were simulated through available analytical solutions and finite difference flow model.

The transmissivity values derived from the pumping tests cover two orders of magnitude and permit to categorize the hard rocks in the classes III and IV according to Krásný’s classification. The storativity is included in a wider range of values. The previous hydraulic properties, together with the simultaneous response to pumping of the drawdown for the piezometer (or piezometers) and the pumped well, may permit to treat the aquifer as a porous equivalent medium at the volume scale of the pumping test. All these properties, associated with an appreciable aquifer recharge, make these aquifers of interest for the local water supply. In this regard, some suggestions to define the sustainable yield of a single well may be derived from the comparison of results of pumping tests with the performed simulations. The results show that the long-term trend in the drawdown and the initial thickness of the aquifer constrain the sustainable yield of a well. In the worst cases examined, the sustainable well yield is from 1 to 2 L/s. These well discharge values are significant if compared with those found in other regions of the world.

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Session Classification : Parallel

Track Classification : Topic 3 - Groundwater sustainability and governance
Inferring groundwater recharge associations to climate, land use and geological structures using multi-decadal groundwater level observations from the semi-arid Limpopo basin of South Africa

Monday, 23 September 2019 12:15 (15)

Keywords: Episodic recharge, WTF-method, 1D-modelling, climate, Limpopo basin

Determining the long-term sustainability of groundwater use in arid and semi-arid regions with high climate variability requires an understanding of the recharge processes that replenish the aquifers as well as their major drivers significantly affecting their temporal and spatial variability. Four hydrographs that range from 42 to 46 years in duration, each within deeply weathered gneiss, were chosen on the basis of their proximity to rain gauges, interpretability throughout, and visible evidence of recharge events in the records. Recharge is quantified using: (1) the Water Table Fluctuation method, applying an inverse approach to estimate recharge from the event-based rises in groundwater level at daily and monthly time-steps; and (2) the HYDRUS 1D model: computing recharge using a dynamic soil-moisture balance model incorporating rainfall, evapotranspiration, soil properties and vegetation characteristics. The hydrographs show that groundwater levels after each rainy season, Oct-Apr, are highly variable in terms of recovery from the previous dry season levels though large episodic recharge events disproportionately contribute to groundwater replenishment. Hence, characterising these recharge events further and their relationship to climate and land use is pivotal to understanding and predicting long-term aquifer sustainability within the wider framework of climate resilience. Correlations from our records show a tendency for episodic recharge to occur during La Niña years, but not strongly enough to act as a predictive tool for significant recharge years. Finally, we provide evidence of focused recharge from surface water bodies, likely in cases further promoted by preferential flow pathways along geological structures like fractures and dikes typical of the region.

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Session Classification : Parallel

Track Classification : Topic 3.1 - Groundwater and water security in developing countries
Integrated approaches to characterize Cenozoic clay-rich layers and investigate their role in regional groundwater flow; Dutch case studies

Thursday, 26 September 2019 17:00 (15)

Worldwide growth in multiple uses of the subsurface, as well as environmental concerns related to these activities have increased the need for better understanding of the subsurface, including its hydraulic properties and groundwater flow conditions, at greater depths than those conventionally studied for water supply purposes. Clay-rich sedimentary sequences may be barriers for fluid flow, and as such of key importance for evaluating their sealing capacity for e.g. geological storage of water, energy and wastes, and for hydrocarbon accumulations at these greater depths. In the Netherlands, data and information from oil and gas wells and petroleum-related studies at these greater depths provide direct measurements of properties of reservoirs and fluids therein (porosity, permeability, pore pressures), but not of clay-rich sequences.

There are a number of indirect local and regional data and methods available, though, that can be used to estimate pore pressures or hydraulic heads in clay-rich sequences, such as pressures in adjacent or enclosed permeable units, and methods using mud weights, wireline logs, seismic interval velocities, and (basin)modelling. The integrated application of these methods to estimate pore pressures will be illustrated with case studies of Paleogene clay-rich sequences in onshore and offshore Netherlands. Basin modelling and knowledge on the regional geological setting are used to interpret the assessed variation in pore pressure distribution and the role of the clay-rich sequences in the regional groundwater flow system.

The focus of an onshore Dutch case study concerns the assessment of the spatial variation in porosity and permeability of the Oligocene Rupel Clay Member (~ Boom Clay). The Rupel Clay is present across the country at burial depths from near surface to 1500 m. Porosity and permeability or hydraulic conductivity measurements of the Rupel Clay are limited to measurements at shallow depths of about tens of meters below surface. Grain sizes measured in samples of the Rupel Clay from different locations spread across the country were used to generate new porosity and vertical permeability data at greater burial depths. Effective stress and clay content are important parameters in the applied grain-size based calculations. The spatial variation in lithology, heterogeneity, and also burial depth, is apparent in the variation of the calculated permeability. The samples in the north of the country consist almost entirely of muds with vertical permeability of less than 8.3E-19 m² (8.3E-12 m/s). The vertical variation in permeability in the more heterogeneous Rupel Clay Member in the southern and east-southeastern part of the country can reach several orders of magnitude due to increased permeability of the intercalated coarser grained sandy-mud and muddy sand layers. The calculated porosity and permeability values were used as input in large-scale groundwater flow modelling to study groundwater flow velocities across the Rupel Clay.
Track Classification: Topic 5.4 - Innovative approaches for understanding groundwater flow systems
Groundwater flooding – assessment of different engineered flood relief schemes using semi-distributed modelling of karst system

Monday, 23 September 2019 17:30 (15)

A characteristic of much of the karst in Ireland is its low-lying nature, with many springs discharging at or below sea level. The low hydraulic gradient for such karst networks also promotes a lot of groundwater-surface water interactions with many ephemeral lakes, known as turloughs, appearing over periods of high recharge (normally in the winter) in topographic depressions. These turloughs are designated as groundwater dependent terrestrial ecosystems (GWDTEs) by the Water Framework Directive and are also designated as Priority Habitats in Annex 1 of the European Habitats Directive due to their unique ecology created by the intermittent hydrological environment.

However, extreme rainfall conditions can lead to high levels of groundwater flooding which is disruptive to the local population, flooding road and rail networks, houses and large areas of agricultural land which, unlike fluvial flooding events, normally takes much longer to recede. This paper documents the history of different studies and attempts to understand the hydrogeology and impact of groundwater flooding for an area of lowland karst in south Galway, centred on the town of Gort. This area has experienced several extreme groundwater flood events over the past 25 years (particularly in 1989/90, 1991, 1994, 2009 and 2015/6) which have created much disruption. There have been two major studies on the catchment which have aimed to design flood relief infrastructure for the area, with the latest one currently nearing conclusion. This paper documents all of the groundwater hydrological studies carried out over the years used to generate insights into the karst plumbing of the area, including anthropogenic and geogenic tracer studies, cave diving, borehole and turlough level monitoring, meteorology and allogenic river flows. These field data have been used to develop a series of conceptual and numerical models ending up with an extensive semi-distributed model based on a pipe network approach (including diffuse recharge) currently being used to design high level flood relief overflow channels. In addition, a new methodology by which specific groundwater flood frequency design events have been defined is detailed. Such statistical analyses of groundwater flooding requires a different approach to design storms typically used for fluvial flooding, as they are more a function of antecedent cumulative rainfall events and surface water levels than just single rainfall events. This process by which climate change forecasts have been incorporated into the target design events is also outlined.

Finally, the process by which different flood relief options were selected to bring down extreme flood levels whilst not interfering with the more natural ecohydrological wetland function of the turloughs is described. In addition, the socio-economic tensions between the pressure from local NGOs who want the scheme built against the central government’s financial responsibility to the wider population is considered.

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**Session Classification**: Parallel

**Track Classification**: Topic 5 - Tools, methods and models to study groundwater
The Castleton karst (Derbyshire, UK) is at first sight typical of many karst systems worldwide. There are inputs of allogetic water from streams that sink at 15 points and inputs of autogenic water fed by rain and snow falling onto the soil-covered limestone outcrop which is pitted by dolines. Water output takes place from three springs that feed a surface stream, the Peakshole Water. Between sinks and springs there are 45 caves with a total surveyed length of over 38km. The longest is the Peak-Speedwell system which is upstream of the springs and has around 50 inlet streams of which 20 flow from permanently water-filled 'sumps'. Cave divers have explored over 1000m of these sumps one of which descends to a depth of at least 76m below dive-base. Over 50 water-tracing experiments have revealed the broad outline of the underground hydrology but there is a great deal of internal complexity that is yet to be fully understood. From July 2012 to April 2015 water depth and temperature were measured at 1-minute or 2-minute resolution in the two main inlet sumps in Speedwell Cavern, at the three springs, and in the Peakshole Water. The data reveal a greater level of complexity than is present in any published data set that I am aware of. The sumps, several hundred metres apart and at different elevations, exhibit both flow switching (the bulk of the flow from the allogetic sinks sometimes entering via one and at other times via the other) and nonlinearity (rapid changes of depth and temperature but with no consistent periodicity). Depth changes can be as rapid as +20cm and -18cm per minute. From the inlet sumps vadose streams flow to a downstream sump that connects with the springs. Some of the complexity is retained in the spring output response (depth changes of up to +8cm and -8cm per minute) and in the stream-discharge downstream of the springs. For example, in one event the discharge fell from 1429L/s to 822L/s over a 54 minute period and then rose back up to 1429L/s over the following 142 minutes. The data pose three questions for karst hydrogeologists and modellers: (1) how can an apparently simple system (when seen in plan) develop such a complex response to recharge; (2) are there any tools that would allow deductions to be made on the system geometry purely based on the output and (3) are there any tools that could provide a reasonable prediction of output.

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Session Classification : Parallel
Track Classification : Topic 7 - Karst Hydrogeology
At an urban landfill facility located in central Italy, we investigate the processes leading to moderate amounts of VOC in groundwater (benzene), at one downgradient monitoring well. Increased alkalinity and sulfates, lower pH and high levels of redox-sensitive elements (Mn, Fe, As), might support both the hypothesis of leachate loss to groundwater or landfill gas-to-water transfer.

In this study, we analyze the available information concerning geochemistry, organic contaminants, environmental isotopes and landfill gas in groundwater to shed light on the possible mass transfer processes. We test the hypothesis that landfill gas migrating from the landfill at the downgradient end of the plant be responsible for high dissolved organic carbon (from methane and other organic compounds), lower pH (due to CO2), and the presence of limited amounts of VOCs transferred from the landfill gas to the groundwater.

Periodical groundwater monitoring campaigns have been conducted since 2016 at the site. Field parameters (T, EC, pH, DO, ORP) are measured with probes in a flow-through cell. Groundwater sampling is performed with an in-line device in order to minimize sample disturbance. Lab analysis are performed for major and trace elements. Organic compounds include DOC, PAH, PCB, VOC. Ammonia and sulphide are measured in the field with a portable UV-VIS. Environmental isotopes (18O, 2H, Tritium, 13C) have been assessed twice. The pressure of CH4, CO2, O2 in the piezometer free gas phase are measured in situ with Draeger X-am 7000 (CO2, O2) and laser INSPECTRA® LASER (GAZOMATTM) (CH4); dissolved gas in groundwater is analyzed by gas chromatography on the headspace.

Groundwaters are mostly anoxic (DO < 1 mg/L), with neutral to slightly basic pH and calcium-bicarbonate facies. Iron, manganese and arsenic are above national standards for groundwater. PAH, PCB and VOC were always below the standards except benzene at one downgradient well. The downgradient well stands out also for high EC, high alkalinity, low pH, very high As, Fe and Mn, above average DOC. Preliminary results on the landfill gas measurements indicate that methane is present both in the free phase in the wells' headspace and as dissolved phase in groundwater.

The high values of methane support the hypothesis of a gas-phase transport of VOC localized at the downgradient end of the facility. Landfill gas CO2 might enhance the dissolution of carbonate minerals and increase alkalinity. The reducing capacity of CH4 favours the high levels of redox sensitive elements in groundwater. While the plant manager has already improved the gas extraction system, a sampling campaign is planned in spring 2019 to further investigate the impact of landfill gas on groundwater and verify the efficacy of the gas recovery measures.
ogy and Geoengineering); PATROLECCO, Luisa (National Research Council - Water Research Institute); SCIARRA, Alessandra (Istituto Nazionale di Geofisica e Vulcanologia)

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**Session Classification:** Parallel

**Track Classification:** Topic 8 - Groundwater quality and pollution processes
Numerical simulation of water flow through observation boreholes: Measurements with Colloidal Borescope (CB) and In-Wel-Point-Velocity-Probe (IWPVP)

Thursday, 26 September 2019 15:15 (15)

We study water flow through observation boreholes using coupled numerical simulations of Navier-Stokes (in open spaces) and Darcy flow (in porous media) using COMSOL Multiphysics. The objective of this work is to analyze different measuring techniques used in observation boreholes such as dilution tests, Colloidal Borescope (CB) and In-Well-Point-Velocity-Probe (IWPVP). We also incorporate the Point Velocity Probe (PVP), which is directly buried in the aquifer instead of inserted in an observation borehole. In our numerical simulations and interpretation, the water velocity field along the whole borehole volume and through the borehole slots is solved explicitly. Screen geometry (slot opening, distance between slots etc.) as well as shape of different devices inserted in the borehole (such as the CB or the IWPVP) can be explicitly considered to analyze how they disturb the water velocity within the borehole.

Interpretation of measurements taken in boreholes requires the conversion of observed borehole velocity $u_0$ to aquifer Darcy flux $q_{inf}$. This conversion is typically done through a proportionality factor $\alpha = u_0/q_{inf}$. In this contribution we present numerical simulations of IWPVP measurements. For the case of IWPVP, experiments conducted in a controlled sandbox are used to compare alpha values obtained numerically with those measured in the lab and test how screen geometry (number of slots, length and opening of slots, screen width and diameter etc.) as well as orientation may influence observed velocities in the borehole. The results of IWPVP deployment at ADYCHATS pilot scale site are also discussed to analyze the implementation of IWPVP in the field scale.

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Developing a structured groundwater database for hydrogeological interpretation as a tool for sustainable groundwater management in Guinea-Bissau (W Africa)

Monday, 23 September 2019 11:15 (15)

Guinea-Bissau is a small West African Country characterized by a tropical savannah climate and an almost flat morphology. Although the yearly rainfall is high (around 2000 mm in Bissau), about 30% of the total population has no access to safe water (2015) and several villages are not reached by mechanized drilling programs. Exploitation of groundwater is fundamental to improve this situation, but the scarcity of information and the low quality of the data limit the hydrogeological knowledge of the territory by technicians and scientists.

The research has been developed through a positive collaboration between University of Milano-Bicocca, University of Padova, UNICEF Bissau and the national water authority (DGRH – Direção Geral dos Recursos Hídricos). Our purpose is to support DGRH in the systematic organization of the large amount of information available and in the efficient management of a well-structured groundwater database.

Borehole-log data have been processed with specifically designed software (i.e. TANGAFRIC and spMC) that allow the extraction of hydrogeological parameters from the logs and the spatialization of the textural characteristics.

The collaboration UNICEF-DGRH started in 2016, with the introduction of a new database structure and procedure for data collection and organization. This method is based on the web platform mWater Portal (portal.mWater.co) which allows to manage a Water, Sanitation and Hygiene (WASH) information system at national scale, with the possibility to display and monitor the inventory of water points. With the technical support of the Italian Universities, a clean dataset of about 800 litho-logs has been extracted. The stratigraphic description is standardized and organized in such a way that TANGAFRIC could process the data automatically. Through this software a limited number of standard categories, describing the lithological characteristics of each log, were assigned meter by meter. This allows the automated extraction of different textural parameters and the estimation of hydraulic conductivity at log level. In the following step TANGAFRIC’s output have been integrated into the spMC package which allows the spatial simulation and prediction needed for the lithological reconstruction of subsurface. In particular, we are looking for possible correlation between the water quality and the lithological bodies geometry and trend, focusing on the Catió Sector (SW Guinea-Bissau), where groundwater is affected by salt intrusion and high iron concentration.

The research is demonstrating the potentiality of a properly organized groundwater database, developed from the information available in a low income African Country. The integration of specific tools for data collection and organization, together with software for hydrogeological interpretation has made possible to improve the knowledge of the hydrogeological context at national level.

The proposed procedure is simple, innovative and easily replicable in other African Countries where an adequate strategy for groundwater exploitation and management could contribute to improve living conditions.
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Session Classification : Parallel

Track Classification : Topic 3.1 - Groundwater and water security in developing countries
Geophysically based modeling of preferential flow

Preferential flow has growing importance in several research fields such as groundwater supply, contaminant transport and geotechnical engineering. Modeling of preferential flow allows for the estimation of its influence on the hydrogeological settings of a study site since preferential flow can alter the velocity and rate of groundwater flow by several orders of magnitude. Geophysical methods such as resistivity tomography and self-potential mapping have been frequently employed for the identification of preferential flow paths in subsurface.

Self-potential mapping and resistivity tomography were applied on a real-world study site at Deisermillen, in the Upper Mosel River Valley, Luxembourg. In 1964 a dangerous landslide occurred at the study site which destroyed several residential buildings and a regional motor road. Thereafter, three investigation campaigns were conducted which delivered a detailed insight into the lithological and hydrogeological settings of the study site. On the study site conductive colluvium sediments overlie less conductive clayey marls. Observations of groundwater heads in piezometer wells and pumping tests indicated an unexpected high rate of groundwater flow in the less conductive marls caused by preferential flow. Geophysical surveys and analysis of drill core records were employed to conceptualise and parametrise preferential flow in a numerical model.

The geophysical investigation showed possible preferential flow paths in the subsurface, however discrimination between different groundwater flow systems in the uppermost colluvium and preferential flow conduits in the deep-seated marls was not possible. Therefore, a detailed analysis of drill core records and an observation of groundwater heads in piezometers were employed in conjunction with pumping tests. A lateral preferential flow conduit was identified in less conductive sediments of marl which probably resulted from the dissolution of a thin gypsum interlayer. A 3D fully coupled physically based hydrogeological model was compiled for the study site using the HydroGeoSphere code. The lateral preferential flow conduit was integrated into the model’s domain by adapting the model’s mesh and sublayers which allowed for the attainment of an exact correspondence between observed and modelled groundwater heads.

This study shows that the newest numerical models allow for modeling of the preferential flow with a high degree of precision, however conceptualization and parametrisation of preferential flow paths in a numerical model based on geophysical surveys is not straightforward. Therefore, additional sources of data such as from the analysis of drill core records and hydrogeological field tests are necessary.

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Session Classification: Parallel

Track Classification: Topic 5 - Tools, methods and models to study groundwater
Sustainable development of groundwater resources under salinity and climate change impacts in Great Maputo, Mozambique

Monday, 23 September 2019 16:00 (60)

The area of Great Maputo in Mozambique, located on the south-eastern coast of Africa is facing a severe water crisis. Due to growing demand and a problem of groundwater salinity, freshwater resources are under extreme pressure. The ongoing drought has further worsened the water supply situation, and in future, the climate variability is imposing an additional threat. Therefore, a study is carried out to understand the impact of seasonal and inter-annual fluctuations in the rainfall on the groundwater resources. The main focus is to address the potential consequence of future climatic variations on groundwater development, with a possibility of enhancing aquifer recharge.

To address the objectives, a transient groundwater flow and chloride transport models are developed for a baseline period of 2010-2018. Transient groundwater recharge is computed by soil-water balance method to analyse the seasonal fluctuations. The baseline models are tested for three scenarios: 1) climate change for a period of 2019-2100 by incorporating Regional Climate Model (RCM) projected data; 2) groundwater development by modelling an optimized distribution of abstraction wells; 3) managed aquifer recharge (MAR) by changing vegetation cover in the study area.

Results of the baseline model indicated a rapid depletion of groundwater storage after the start of severe drought in 2015, with a drop in water levels that is more pronounced in the urban areas. The results highlight that western and northern regions contain brackish to saline groundwater, due to seepage of entrapped fossil saline water from the semi-permeable aquitard units, also discharging as baseflow into brackish surface waters and wetlands. The eastern part of Maputo City also presents a high groundwater salinity associated with the mixing with seawater in the coastal zone. Climate change is foreseen to affect the groundwater levels and storage in a negative manner in the long-term, but it becomes more threatening when an enhanced groundwater development scenario is coupled with it. The groundwater levels show a drop in all the zones but more noticeably below the Maputo City due to high well density and pumping rates. The integration of newly planned wells by the Water Utility showed a continuous decline in the water levels and increasing salinity over the coming decades. Application of both optimized well distribution and MAR strategies resulted in the inversion of the falling water levels and storage improved significantly.

The importance of these strategies becomes more critical for the sustainability of the groundwater resources in the coming decades due to longer periods of drought. To continue groundwater abstraction and avoid excessive drawdown and groundwater salinization, both optimized well distribution and MAR need to be discussed with the local water resource users, planners and authorities.

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Session Classification : Poster with refreshments
Track Classification: Topic 2 - Groundwater and climate change
DEEP AQUIFERS IN SPAIN: A NECESSARY RESEARCH TO ADAPT TO CLIMATE CHANGE

Monday, 23 September 2019 17:30 (15)

The future scenario of global climate change brings a major challenge for the groundwater resources sustainability. The evolution of groundwater in the coming years forecasts a progressive decline of the water table and a decrease in the streamflow, which implies a reduction of the water reservoir storage. This will have negative consequences not only on the associated natural ecosystems, but also on the resources focusing on water supply, among others.

Underground hydrological resources considered in river basin management plans include those belonging to aquifers that have a link with natural ecosystems, and those associated with aquifers that support the main supplies. The resources under the usual withdrawal depths are not taken into account because they are considered as non-renewable resources, in addition to the pumping cost or its assumed high salinity. In the case of surface aquifers with several hundred meters thickness, the use of groundwater resources is usually limited to the upper part of the saturated zone for the same reasons.

Therefore, under of this non-stabilized depth –variable according to the hydrogeological structure and the climatic and economic local factors– there exists an amount of unexploited groundwater resources, mostly unknown or not yet evaluated. Investigation of deep aquifers is extremely complex and has a high economic cost. Aspects like deep aquifer geometry, hydrogeological and hydrochemical characterization and resources estimation, need complex and specific techniques different from those used in the study of shallow aquifers.

There is a growing interest in the knowledge of deep aquifers because of the climate change context. In the present study, deep aquifers have been considered as deep groundwater reservoirs, regardless the quality or the hydraulic aquifer properties. The main goal is to define some aquifers –or geologic formations– like strategic reservoirs for human use. An adequate characterization of a deep aquifer could be integrated in the groundwater resources management and help to reduce the scarcity in extreme situations.

The Geological Survey of Spain –IGME– has performed the work of improving the knowledge and characterization of deep aquifers in this project. As a starting point, an inventory of deep aquifers has been carried out in the main river basins of Spain –Iberian Peninsula area– under specific selected criteria. The main characteristics have allowed a classification of Spanish deep aquifers. Some examples, representative from different typologies, have been selected for a detailed study as a “deep aquifer” with a proper methodology.

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Session Classification : Parallel

Track Classification : Topic 2 - Groundwater and climate change
Numerical modelling to assess head losses and flow characteristics through water well screens

Monday, 23 September 2019 17:00 (15)

In this communication we develop a methodology to simulate head loss and flow characteristics through water well screens, comparing different screen types and well construction parameters (e.g. well diameter, pumping rate, screen slot aperture, screen open area, hydraulic conductivity of the filter/gravel pack, etc.). We use COMSOL Multiphysics to perform coupled simulations of turbulent fluid flow (across the screen slots and within the well) and Darcy flow (in the porous media such as the filter/gravel pack and adjacent aquifer). Solving Randomly Average Navier-Stokes (RANS) equations for turbulent flow requires implementing the theory of Computational Fluid Dynamics (CFD) for an appropriate turbulence model. Our objective is to set up a methodology to understand how the different elements of a pumping well interact and determine the overall head loss, among other flow characteristics, observed in real pumping wells. At this stage of development, we focus on the hydrodynamic processes taking place at the scale of the screen slot (sub-mm). We formally define the screen head loss as the difference between average hydraulic head of inner- and outer- screen surfaces. We compare the behavior of 4 different screen types available in the market: Louver screen, Wire Wrap screen, Bridge screen and vertical slotted screen. For solving the flow efficiently, we build a cylindrical sector from the well bore to the rock formation that includes a defined “unit cell” for each screen type having appropriate symmetry and/or periodic boundary conditions. The simulations indicate that the screen head loss depends on the screen geometry and slot opening but also depends on the hydraulic conductivity of the filter/gravel pack. The traditional approach to quantify well head loss consists in fitting an equation of the form BQ+CQ^2 to step drawdown tests. Commonly applied methodologies associate the “screen head loss” with the term CQ^2 through the “orifice law” (as governing equation for flow through the screen slots) while the term BQ is considered a separate entity, subject to Darcy’s law and the hydraulic parameters of the filter/gravel pack and overall aquifer. Our simulations indicate that the screen head losses are intimately related to properties of the filter/gravel pack, and the “orifice law” underestimates the screen head loss more than one order of magnitude.

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Session Classification : Parallel

Track Classification : Topic 5 - Tools, methods and models to study groundwater
Monitored Vapor flux and groundwater recharge in 2 hydrological years by a precision meteo-lysimeter

Monday, 23 September 2019 15:00 (15)

A high precision meteo-lysimeter was installed 2015 in a coastal dune of the Doñana Natural Reserve SW Spain to quantify water and energy fluxes in dune belts, and to estimate its dependence on regional climate trends. The weighing lysimeter contains an undisturbed soil sample of 1 square meter surface, 1.50 m height with a weighing resolution of 10 g. Furthermore, the site is equipped with 2 automatic meteorological stations, 1 Hellmann pluviometer and six calibrated TDR sensors installed outside the lysimeter at 6 different depths until 3 m below surface. Environmental humidity conditions at the lysimeter bottom were maintained by a peristaltic pump controlled by two tensiometers installed inside and outside of the lysimeter and the volume of the drained water was analysed continuously. A total of 11 meteorological and soil water parameters were recorded in 10 and 1 minuteintervals, respectively. Intrinsic noise in lysimeter data was reduced by smoothing through the AWAT filter (Peters et al. 2014). Precipitation and drained water from the lysimeter was analysed for major ions and stable isotopes of water. Additionally relevant physical and retention curve parameters of the sediment were analysed and the individual fluxes were quantified using lysimeter observations. Monitored data were used to set up a 1D model which was calibrated based on monitored groundwater recharge and TDR time series data. The results of 2 hydrological years with different meteorological conditions and its effect on groundwater recharge and vapor flow are shown.

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Session Classification : Parallel

Track Classification : Topic 5 - Tools, methods and models to study groundwater
Upscaling of transport processes of colloids through unsaturated porous media: Obstacles and uncertainties

The transport of colloids in porous media is affected by several factors including fluids, porous media and particles properties, flow regime, and chemical conditions. Among all, fluid saturation, as a subset of the flow regime, plays a prominent role in mobilization of particles. By changing the fluid saturation, the amount of available solid–water interfacial (SWIs) and air–water interfacial (AWIs) area change. The modeling approaches which consider the influences of AWI and SWI use various empirical or analytic terms. Defining uncertainties associated with those term in pore scale and upscaling implementation into advection-dispersion or other transport equations represents an important ongoing research opportunity.

In this study we tried to make a better understanding of these terms by using the pore network modeling (PNM). As the next step, the obtained model was fitted to simulate a series of saturated–unsaturated colloids transport experiments reported in the literature.

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Session Classification: Poster with refreshments

Track Classification: Topic 5.3 - Advanced modelling tools for subsurface hydrology: from the vadose zone to deep environments
A multi-method characterization of river-aquifer interaction at the meter-scale: combining field measurements, heat transport modelling and groundwater modelling

River-aquifer interactions play an important role in a wide range of major ecological and hydrological challenges. An accurate characterization of these interactions is important for assessing river water quality and riparian ecology, evaluating stream depletion due to groundwater extraction close to rivers, and predicting flood peaks and low flows. Most studies focus on the large-scale characterization of river-aquifer interactions. However, aquifer and riverbed properties can exhibit strong heterogeneity on the meter-scale. Few studies have been performed that focus on the effect of meter-scale spatial variability of these properties on resulting river-aquifer exchange fluxes.

In this study, river-aquifer interaction has been characterized on the meter-scale by combining field measurements, heat transport modelling and groundwater modelling for a stretch of the Aa River, a typical gaining lowland river in the Nete Catchment (Belgium). Field measurements have been performed at two 20m long sections of the Aa River. Both horizontal and vertical riverbed hydraulic conductivity are characterized with respectively falling-head slug tests and rising head standpipe tests. Furthermore, vertical riverbed temperature profiles are measured, and vertical river-aquifer exchange fluxes are estimated with heat transport modelling. The resulting fluxes are compared with river-aquifer exchange fluxes derived from a local groundwater flow model (MODFLOW) and with fluxes calculated with Darcy’s law based on riverbed K and vertical hydraulic gradients. Moreover, geophysical measurements (ERT and IP) are performed at one of the sections of the Aa River to qualitatively map the spatial structure of the riverbed. A geostatistical analysis of riverbed K, exchange fluxes and geophysical properties has been performed to characterize the spatial variability and anisotropy on the meter-scale.

Results show that riverbed hydraulic conductivity is strongly spatially variable and that it varies over several orders of magnitude within several meters. Elongated structures of high riverbed K along the river flow are observed, which are related to deposition and erosion due to high discharge events, and to the presence and thickness of an organic matter layer at the top of the riverbed. Estimated vertical river-aquifer exchange fluxes based on heat transport modelling show a clear spatial variability on the meter-scale. In general, higher fluxes are observed near the river banks. This indicates that the spatial distribution of the fluxes cannot only be explained by the spatial distribution of riverbed K. An inverse correlation between riverbed K and IP geophysical parameters has been identified. However, the relationship is only semi-quantitative. Therefore, it is recommended to use ERT/IP to qualitatively map zones of high hydraulic conductivity and to target sampling locations of K, rather than in a direct quantitative way. Different methods to quantify river-aquifer exchange fluxes are compared, and the influence of the different assumptions behind these methods is shown.

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**Session Classification** : Parallel

**Track Classification** : Topic 5.3 - Advanced modelling tools for subsurface hydrology: from the vadose zone to deep environments
Chalk Aquifer Management (CHARM): Groundwater modelling of a complex aquifer for the sustainable management of strategic drinking water reserves in Flanders (Belgium)

Monday, 23 September 2019 16:00 (60)

Groundwater is an important source of drinking water in Belgium. In some regions, locally produced groundwater is the source of 100% of the drinking water supply. One of the most important aquifers in the eastern part of Belgium is the Chalk Aquifer. This aquifer is phreatic in the northern part of Wallonia, but dips down towards the north, in Flanders, where it quickly reaches large depths. This largely confined aquifer is of strategic societal importance because it is well protected against negative influences from the surface (nitrate, pesticides) on the water quality.

However, geological and hydrogeological information is scarce, leading to important uncertainties regarding sustainable yields. Due to the large depth of the aquifer in its confined part, relatively little borehole information is available. Furthermore, the Chalk Aquifer is characterized by a double porosity system which results in a strong heterogeneity and spatial variability of the hydrogeological properties. The goal of the CHARM project is to analyse the capacity of the Chalk Aquifer on a regional scale, and to deliver a management instrument that can be used for decision-making with regards to the quantitative use of this strategic aquifer for drinking water purposes. Special attention will be given to the characterization of all sources of uncertainty and its incorporation in a groundwater flow model.

In a first step, the geology and hydrogeological parameters of the Chalk aquifer are characterized in detail. Based on gamma-ray logs, flow measurements, pumping tests and literature data, the horizontal and vertical variability of the hydrogeological parameters are identified. Exploitation results are linked to geological and hydrogeological data providing insights why some exploitations have a higher yield than others. Next, a regional groundwater model (MODFLOW) is set-up. The integrated Bayesian multi-model approach of Mustafa et al. (2018) is adapted, so that input, parameter and conceptual model uncertainty can be quantified. This is done by coupling the MODFLOW model with the DiffeRential Evolution Adaptive Metropolis (DREAM) algorithm (Vrugt, 2016) and by applying Bayesian Model Averaging (BMA). Based on the results of this approach, well-founded decisions can be made regarding the quantitative use of this aquifer considering all different sources of uncertainty, which is of strategic importance for long-term drinking water purposes.

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Session Classification: Poster with refreshments

Track Classification: Topic 3 - Groundwater sustainability and governance
Rainwater pipeline project between Paris Charles de Gaulle Airport and the river Marne: assessment and reduction of the impacts of groundwater drawdown operations on wetlands and rivers

Friday, 27 September 2019 11:30 (15)

The objective of the project is to lay a rainwater pipeline between Paris Charles de Gaulle Airport and the river Marne. The pipeline will be 9.2 km long, with a diameter of 1400 mm to 1800 mm at crossings. The project is located in the Beuvronne valley, through which a shallow alluvial aquifer flows. Geotechnical and hydrogeological field investigations were carried out and revealed the presence of six wetlands along the route of the future pipeline. They also showed that the bottom of the trench will be below the water table. Pumping operations will hence be necessary to dry the trench.

Such operations can generate impacts on rivers and wetlands: drying up of wetlands and rivers, deterioration of river water quality, which can have consequences for fish fauna. Impacts can also occur during the operation phase due to the reworking of the land in the trench.

The approach adopted to assess the impacts consists in building a hydrogeological model covering the entire route of the pipeline. This approach is technically complex but is a means of assessing impacts on the various sensitive zones while taking variations in context (proximity of water courses, hydraulic conductivity variations, etc.) into account. With the aid of substantial data from the field investigations, it was possible to design a multi-layer model representing the different formations concerned by the project, draw a piezometric map over a wide area around the future pipeline itself, and calibrate the model in transient conditions by integrating periods representative of the various hydro-climatic conditions that can be encountered, such as high water (flood of the Marne) and low water.

The calibrated model was then used to evaluate the area of hydrogeological influence of the project, the extent of the drawdown cones and the time required for the water table to return to its initial level. It was also possible to specify depth of groundwater drawdown below ground level, an essential parameter for assessing impacts on wetlands, since the hydrological, biogeochemical and ecological functions of wetlands are directly related to shallow waterlogged soils (the first 50 cm in particular). Hydrogeological impacts were then translated into impacts on wetlands by combining the expertise of hydrogeologists and environmentalists.

The study thus made it possible to address the concerns of the various stakeholders (authorities, pipeline owner, etc.) and to recommend appropriate measures to mitigate the project impacts on wetlands, including operational measures during the construction phase (length of open section, prior pumping time, work period, materials and methods for backfilling the trench, etc.) and specific monitoring.

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Session Classification : Parallel
Track Classification: Topic 6 - Groundwater, wetlands and natural heritage
Groundwater management in the Azores archipelago (Portugal): state-of-art and identification of the major constrains

Thursday, 26 September 2019 17:00 (15)

The Azores archipelago is located in the North Atlantic Ocean, between latitude 36°55’N to 39°43’N and longitude 25°00’W to 31°16’W. Formed by nine volcanic islands, the Azores has a total area of 2322 km² and about 243,862 inhabitants (2017).

The Azores archipelago was designated as the ninth River Basin District (RH 9) in Portugal following the adaptation of the EU Water Framework Directive (WFD) to the national law (WL). About 98% of water supply in the Azores archipelago is provided by groundwater abstraction (4.67x10⁷ m³/a) which exceeds by far surface water abstraction (7.94x10⁵ m³/a). Considering that seven out of the nine islands some islands depend strictly on groundwater, sustainable management is an issue of paramount importance.

A total of 51 from the 54 groundwater bodies (94.4%) delimited in the Azores are in good status, being the failures to comply with the WFD criteria due to coastal aquifer salinization and, to a minor extent, problems such as nutrient and microorganism faecal pollution, mainly due to agriculture and waste water discharges, or fluoride local enrichments closely linked to the interaction with volcanic activity.

The administration of the Azores RBD is ensured by the Regional-Directorate for the Environment, from the Energy, Environment and Tourism Secretariat of the Azores government, which is responsible for the overall management and protection of groundwater resources in the archipelago, including water resources planning and the compliance to all legal and regulatory frameworks. The water authority acts in a vertically integrated system with representatives in all the nine islands. Water supply is run directly by 15 of 19 municipalities, corresponding to 47.3% of the Azores inhabitants, and in the remaining municipalities municipal companies (2; 10.8%) or semi-autonomous utilities are responsible (2; 41.9%). Thus the relationship between groundwater science, instrumental toward sustainable development, and the water supply operations is another factor that should accounted for.

Two River Basin Management Plans (RBMP) were already adopted in the Azores. However, the delivery of the RBMP is affected by threatened by several constrains, that can be grouped as follows: (1) low awareness of groundwater significance, (2) legal and regulatory issues not fully adapted to the specific natural, financial, technological and institutional capabilities, as well as to the social and cultural practices, (3) lack of quantitative data, namely the absence of any quantitative monitoring, which also affects legal and institutional capabilities, (4) legal and institutional capacities weakened by the failure to account for the economic dimension of the groundwater, and a specific system for taxation of groundwater abstraction /discharge of pollutants has still to be proposed, (5) low cross-sectorial capacities developed, namely with agricultural sector, resulting from insufficient cooperation and interaction between the water authority and other public and non-public bodies, including water users.

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**Session Classification:** Parallel

**Track Classification:** Topic 5.2 - High island hydrogeology
Groundwater pollution from agriculture activities in the Azores archipelago (Portugal): an insight from a long range monitoring programme data

Thursday, 26 September 2019 16:00 (60)

The Azores archipelago is made by nine volcanic islands, with a total area of 2322 km². Despite GDP in the Azores is dominated by tertiary sector activities, with an increasing tourism pressure, in the archipelago livestock is the main primary sector activity, and as a whole agriculture, livestock production, hunting, forestry and fishing have a GVA of 9.8%, which is about 4-times higher than the country value. Land use is dominated by agriculture, mainly pasture land, with about 56% of the land area, as well by forest (22%) and natural vegetation (13%), and a total of 1.71 livestock units/ha of the utilized agricultural area (129793 ha) were registered in the archipelago in 2016.

About 94.4% of the 54 groundwater bodies currently delimited in the Azores are in good status, being the failures to comply with the Water-Framework Directive (WFD) due to coastal aquifer salinization, namely in Graciosa and Pico islands. However, other groundwater quality problems are observed, despite not being widespread, being nutrients (N, P) from agriculture one of the main drivers of these unconformities. The present paper addresses agriculture pollution of groundwater through data gathered in the last 15 years in the archipelago.

In the Azores RBD only the groundwater chemical status is monitored, a project started in 2003. A total of 69 springs and 32 drilled wells are presently being monitored in nine islands. The percentage of groundwater bodies being nowadays monitored is 64.8% of the total, and considering each island this value range between 33.3% (Graciosa island) and 100% (São Miguel, São Jorge and Flores). Considering only the 35 groundwater bodies being monitored, only 5.7% have representative networks, considering a threshold value of 80% for the representative index computed.

Mean nitrate content for the several springs and wells monitored is on the range between 0.01 and 60.1 mg NO₃/L. Nevertheless, only in two drilled wells, both located on São Miguel island, mean values are above the 50 mg NO₃/L guideline, and in four of the nine islands mean nitrate content is as high as 6 mg NO₃/L.

When computing the mean value for each groundwater body, whenever the amount and representativeness of data allows to, values are in the range of 1.1 to 22.9 mg NO₃/L, thus not affecting the good chemical status according to the WFD. Nitrite mean for the groundwater bodies is as high as 56.2 µg NO₂/L, also not causing failure to comply with the WFD requirements. Nevertheless, the phosphorous content in some springs and wells exceeds the 400 µg P₂O₅/L threshold value defined for the Azores RBD, and in one of the groundwater bodies the mean value is also higher that the latter guideline value, resulting from the application of phosphate fertilizers.

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Session Classification : Poster with refreshments

Track Classification : Topic 5.2 - High island hydrogeology
Advances in Groundwater Monitoring

Monday, 23 September 2019 11:30 (15)

Understanding groundwater resources and their informed management ask for regular monitoring of groundwater state variables, both quantity and quality. Collected observations need to be stored, processed and shared among stakeholders. The Global Groundwater Monitoring Network (GGMN) assists (already since 2007) in improving the quality and accessibility of groundwater information and eventually the understanding of the state of groundwater resources (www.un-igrac.org/ggmn). This abstract summarises some advances in data collection, processing and sharing, accounted within GGMN activities.

Although automatic groundwater monitoring and even telemetric transmission of data are becoming widely used, manual collection of data is still present or even predominant, the choice depending on parameters and purpose of the monitoring, groundwater regime, available resources, and others. In order to facilitate data collection in the field and data transmission to the GGMN Portal, a mobile (smartphone) application is recently developed. This GGMN App enables users to georeference and register groundwater monitoring wells, store groundwater monitoring data in the field and (immediately or later if WIFI is not available) transfer data to GGMN and store it there. In GGMN, data can be processed and optionally shared with other data providers and stakeholders.

One of the most effective ways to share time series data among online data portals is through an automated Sensor Observation Service (SOS). This service has been recently implemented in GGMN and tested by connecting GGMN and the Groundwater Information Network (GIN) of the Geological Survey of Canada. Since GGMN aims to serve as a global monitoring focal point, the ultimate goal is establishing the same or comparable data sharing services with as many as possible national groundwater services around the world.

IGRAC is preparing a global overview of national groundwater services with a focus on temporal and spatial processing of groundwater observations. It is a general impression that collected observations are not processed sufficiently. On the other hand, some services exhibited creative approaches in the processing of (in particular) spatial variability of groundwater variables. These approaches will be promoted through the IGRAC global overview and some of them are considered to be implemented in GGMN soon.
A multi-isotopic approach to evaluate the origin of Fluoride in groundwater in the Main Ethiopian Rift Valley

Thursday, 26 September 2019 16:00 (60)

In the Main Ethiopian Rift Valley (MER) high levels of fluoride (F-) in drinking water supply, commonly associated to the geologic substratum, are recognized as one of the major public health problems in most rural villages, where the majority of population exhibit various degrees of fluorosis symptoms.

To better define the origin and dynamic of this contamination, a multisotopic investigation (δ18O and δ2H of H2O, δ15N and δ18O of NO3, 87Sr/86Sr, δ11B and 3H) has been implemented within the frame of the H2020 FLOWERED Project (http://www.floweredproject.org) for a portion of the MER, complemented by a conventional hydrochemical study.

Beside the geochemical-statistical estimation of the fluoride background concentration in groundwater based on literature data, two field surveys were carried out. The target area was divided in three physiographic zones: the rift, the transitional escarpments and the plateau. Specifically, the escarpment and the low-lying rift are mainly covered by Late Pliocene and Quaternary volcanic rocks, and both lacustrine and alluvial sediments. Aquifer systems are often confined or semi-confined in the fractured and/or weathered volcanic formations and phreatic in the sediments covering parts of the rift floor. The sampling were performed along both transversal (from the plateau to the Rift floor) and intra-rift (along the Rift floor) transects within the main aquifer formations with the purpose of highlighting the difference between groundwater from Rift-parallel flow and escarpment-to-Rift flow.

Groundwater evolves from Ca–HCO3 to Na–HCO3 type in the plateau and in the Rift floor respectively. In general, most of the groundwater fall on the local meteoric water line, indicating a meteoric origin. Deep boreholes waters, both located in the Rift floor and in the escarpments, showed long residence time although, for the former zone, shorter residence times were detected especially for the water interacting with lake waters.

Higher concentrations of F−, above the permissible limit for drinking water, were detected along the Rift floor zone. Notwithstanding, high values were detected also in correspondence of the plateau zone but just for the thermal waters. Fluoride origin was found to be not exclusively related to geologic sources, since a strong relationship with organic and inorganic pollution sources, attributable to both untreated sewage and synthetic fertilizer, was identified.

The results inferred through the use of a hydrochemical and multi-isotopic approach represent an appropriate tool for differentiating geogenic and anthropogenic sources of fluoride contamination and correctly address protection and remediation strategies of water resources.

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A multi-isotopic approach to evaluate...

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Session Classification: Poster with refreshments

Track Classification: Topic 8 - Groundwater quality and pollution processes
Atrazine y desethylatrazine distribution in the natural reserve of Pétrola saline lake after 12 years of prohibition

The catchment area of the Pétrola lake-aquifer system supports agricultural and livestock activities. Two types of farming are present: dryland farming and irrigation. Farming encompasses approximately 75% of the total area, whereby dryland farming contributes about 58% and irrigated cropland 17%, based on data from Corine-Land Cover 2012. The use of inorganic synthetic fertilizers, as well as wastewaters from Pétrola municipality, constitute the main source of nitrogen in the system. Linked to the presence of anthropogenic derived nitrogen, the appearance of organic pollutants in the environment is common. One of the most deployed herbicides in Spain from 70s was atrazine. This pesticide was banned in general in Europe in 2004, with some exceptions in countries like Spain, Portugal, Ireland or United Kingdom, where its use was allowed until 2007. One of the reasons for this prohibition was its high persistence in the environment; in fact, in Germany has been recorded the presence of this herbicide in groundwater 21 years after its ban in 1991.

In the endorheic basin of Pétrola saline lake (SE Albacete), a complete monthly (March to November 2018) hydrochemical characterization was carried out in surface lake waters, ephemeral streams and springs from surrounding areas of the lake. The determination of atrazine and desethylatrazine was carried out with a gas chromatography coupled to a mass detector (Agilent 7890 GC System, 5977B MSD) qualitatively in scan mode and quantitatively in single ion monitoring (SIM) mode. A total of 121 samples were analysed. Atrazine and desethylatrazine were only detected in those points associated to agricultural land uses. These pollutants were not detected in water points linked to urban wastewater or livestock activities.

From March to June, atrazine was detected at surface lake water (concentrations between 104.48 and 195.01 ng/L), as well as in streams and spring (reaching values up to 264.43 ng/L). However, from July to November, atrazine was not detected. From March to November, this compound was detected in both streams and springs. The most complete record was obtained in one spring (sampling point 2571), in which desethylatrazine was measured five times (37.31 ng/L - 228.54 ng/L). In spite of non-reactive transport processes can be effectively involved in the groundwater distribution of these pollutants, previous studies allowed to infer the presence of reactive processes (denitrification, sulfate reduction), driven by the interaction of saline surface water and fresh groundwater, which can attenuate the presence of atrazine and desethylatrazine in the environment.

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Session Classification: Poster with refreshments
**Track Classification**: Topic 8 - Groundwater quality and pollution processes
Aquifer Dynamic Characterization Tools System: the ADYCHATS industrial pilot site for better understanding of mass flux in groundwater

Thursday, 26 September 2019 15:00 (15)

In the TOTAL R&D Program on Environmental and Societal Stakes, ‘Soil and Groundwater’ is one of the primary environmental compartments of interest to better characterize and monitor for long-term and sustainable exploration, production, refining, manufacturing and services operations. Over the last few years, studies have been dedicated to creating a research and development platform to address the challenges of shallow and deep groundwater dynamic characterization and monitoring on industrial sites. The ADYCHATS industrial pilot (standing for Aquifer DYnamic CHAracterization Tools System) was launched in 2018 on a 6-ha experimental area of TOTAL R&D Lacq Research Center (PERL), within the historical industrial platform of Lacq in the southwest of France. The alluvial geology of the shallow unconfined aquifer is primarily comprised by unconsolidated coarse gravel deposited by the Gave de Pau (river of Pau) with spatially discontinuous interbeds of sandy and loamy gravels. Currently, 20 piezometers have been installed to an average depth of 6 meters and operate permanent or punctual probes for classical temperature, pressure, and conductivity measurements. Periodic exhaustive surveys are being performed several times per year to measure the physical and chemical parameters of the groundwater at the time of, or shortly after, sampling. Innovative tools have been also deployed to measure groundwater velocity. Multi-level Point Velocity Probes (PVPs) containing two probes per stand have been installed directly in the unconsolidated porous media to measure the groundwater pore-water velocity at five locations and two depths, corresponding to two distinct hydrostratigraphic facies. The first results of PVP measurements showed measurements of direction consistent with the global piezometric map of the site. These measurements reveal structural heterogeneities at or below the meter scale that have to be taken into account for a better understanding of preferential pathway for potential solute transport in groundwater. In parallel, In-Well Point Velocity Probes (IWPVP) have also been deployed in piezometers to estimate the Darcy velocity, direction and magnitude, in the surrounding aquifer and further validate the PVP measurement results. PVPs directly measure the porewater velocity but require dedicated boreholes that collapse against the probe. IWPVPs are multi-use instruments that can be installed and removed from monitoring wells. However, the IWPVP measures a groundwater velocity through a probe seated within the well screen which must then be calibrated to estimate the Darcy velocity within the surrounding media (or porewater velocity correcting for the effective porosity). In the future, near simultaneous groundwater velocity measurements will be conducted. The final aim of the studies performed on ADYCHATS pilot is to provide an in-situ, real time, continuous and cost-effective network of tools and methods for dynamic characterization and monitoring of groundwater flow and mass flux.

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Session Classification: Parallel

Track Classification: Topic 5.1 - Dynamic Analogues
Recharge processes and groundwater age along the hyperarid western edge of the Andes (Atacama Desert): fossil groundwater recirculation

Monday, 23 September 2019 16:00 (60)

The assessment of groundwater recharge processes is mandatory for the sustainable use of aquifers, especially in arid environments. In the literature, natural recharge processes (i.e. direct or indirect addition of water to the saturated zone of an aquifer from the ground-surface) are exclusively related to the contemporary (or coexisting) hydroclimatic context. Along the hyperarid western edge of the Andes, in the Atacama Desert (Northern Chile), recent findings in the Andean Piedmont have revealed a hydraulic correlation between aquifer recharge areas and perennial river losses areas. In this hyperarid area, where mean annual precipitation below 2000 m a.s.l are less than 10 mm yr⁻¹, the perennial base flow originates from springs in the bedrock of the Precordillera. In studies performed during the 1980s and 1990s, carbon and water isotope analyses of base-flows revealed that groundwater stored in the bedrock of the Andes is old and related to another hydroclimatic context than the current one.

This work addresses the role of fossil groundwater recirculation in the renewal of groundwater of the regional scale Pampa del Tamarugal Aquifer. This study analyses ¹⁴C, δ¹³C, δ¹⁸O and δ²H isotopes of surface and groundwater in the Quebrada de Tarapaca catchment (19.8°S). In the Precordillera and the regional aquifer, groundwater recharge occurred during the late Pleistocene wet phases related to the Bolivian Altiplano paleolakes (Tauca and Coipasa). Depleted δ¹⁸O and δ²H isotopes, disconnected from modern precipitation, agree with the cooler and wetter climate of the late-Pleistocene. In the bedrock of Precordillera, the observed constancy of water isotopes for 50 years highlights both the disconnection of groundwater from modern precipitation and the fossil nature of groundwater. In the area of perennial river infiltration, ~80% of groundwater isotope content match with the water isotope content of these perennial rivers base-flow. Numerical modeling of vadose zone processes shows that and 90% of this base flow recharge the aquifer (~180 l.s⁻¹ for Quebrada de Tarapaca) while only 10% goes to evaporation.

Fossil groundwater recirculation appears to be a significant process in the renewal of groundwater of the Pampa del Tamarugal Aquifer. It implies to reconsider the real proportion of modern precipitation in the current recharge of the Atacama Desert aquifers, but also to reconsider the basis-concept of recharge usually assumed for such aquifers.

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**Session Classification:** Poster with refreshments

**Track Classification:** Topic 1 - Groundwater assessment and management
Using recession analysis to identify and characterize changes within a karst aquifer (Lurbach system, Austria)

Thursday, 26 September 2019 16:00 (60)

As shown by Mayaud et al. (Carbonates Evaporites, 2016), the hydrograph of the Hammerbach karst spring (Lurbach system, Austria) in the years after a flood event in 2005 is markedly different from that in the time before. In particular, the recession is slower and the discharge values vary only within a range narrower than in the years before the flood event. Observations in accessible parts of the karst system, hydrological modelling (Wagner et al., Grundwasser, 2013), and analysis of changes in the thermal responses of the spring (Birk et al., Environ. Earth Sci., 2014) suggest the hypothesis that the redistribution of sediments in the course of the flood event created constrictions within the conduit system, which are the cause of the observed changes. This hypothesis further implies that the system potentially can return to the previous flashier behaviour if the accumulated sediments are remobilized during subsequent flood events. Unfortunately, the above-cited previous work is based on data until 2009 only. A tendency towards a flashier behaviour was apparent at the end of the year 2009, but needs to be further substantiated by the analysis of more recent data. For this reason, this work analyzes the hydrograph of the Hammerbach spring using data until 2015. From 2009 onwards, the annual maximum discharge was always higher than in the time period from 2005 to 2008. In 2012, also the baseflow approached values lower than those observed between 2005 and 2008, but a general return to lower baseflow values appears to be less obvious. In order to provide reproducible measures of the recession characteristics, we thus employed the EXCEL VBA algorithm by Posavec et al. (Groundwater, 2017) to construct master recession curves for various time intervals. Although the results are found to depend on the choice of the construction method and the length of the time intervals, the recession characteristics of the years after 2009 indeed are found to be clearly different from those in the time from 2006 to 2008 and similar to those before 2006. This finding supports the hypothesis that the flood event in 2005 had caused only temporary changes in the aquifer properties.

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Session Classification : Poster with refreshments

Track Classification : Topic 7 - Karst Hydrogeology
Meeting the challenges of sustainable groundwater development and management in emergency response: a joint initiative by Groundwater Relief and Médecins Sans Frontières Holland (MSF-OCA) to build understanding about the Tipam Sandstone Aquifer whilst meeting immediate needs of refugees in the Mega camp of Cox’s Bazaar, Bangladesh

Monday, 23 September 2019 18:15 (15)

The Cox’s Bazaar District in Bangladesh is hosting a massive rapid influx of over 700,000 Rohingya Refugees from Myanmar, placing huge strain on local resources including water resources. The largest camp, known as the Mega Camp, is spread across a 13km2 block of land between Kutupalong and Balukhali. Water supply for this camp is sourced from the underlying Tipam Sandstone Aquifer. The aquifer comprises over 400m of loosely compacted and structurally deformed Miocene aged sandstone. To date, the Tipam Sandstone Formation has received little study but is being pumped at an unprecedented rate. A sustainable water supply for all residents of the Mega Camp and surrounding areas depends on a sound conceptual understanding and carefully managed development of the underlying groundwater resource. With this aim in mind, Groundwater Relief in collaboration with Médecins Sans Frontières Holland, have been engaged in collecting groundwater data since January 2018 across a 7km2 area. New boreholes drilled have been logged and pumping tests carried out. A monitoring programme was established including the installation of 10 water level data loggers across a network of monitoring and abstraction boreholes; the set up of three rain gauges; and a monthly water quality monitoring programme across 12 boreholes measuring basic field parameters. Hydrographs comparing rainfall with groundwater levels relative to sea level showed groundwater levels quickly increased on the onset of the rainy season with a 1.5m increase over one month in July 2018. Groundwater levels increased almost simultaneously to peak rainfall events, suggesting rapid infiltration and recharge. Elevated ferrous iron concentrations were encountered in the top 120m of the aquifer with lower concentrations found at greater depths. Electrical Conductivity values in the groundwater are significantly below the Bangladesh Standard of 1500 μS/cm at present.

Over the course of 2019 Groundwater Relief is working with Dhaka University and the International Organisation for Migration to expand the monitoring programme across the entire Tipam Sandstone Outcrop in Cox’s Bazaar. As part of this programme a groundwater model and management tools will be developed to support the Bangladesh Authorities with the planning of new water supplies for the camp and the host population.

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Session Classification: Parallel
Track Classification: Topic 3.1 - Groundwater and water security in developing countries
Hydrodynamic and heat transport 3D modelling of the Pannonian Basin, HU-SRB-RO - pilot area of the DARLINGe project

Friday, 27 September 2019 12:00 (15)

The main aim of the DARLINGe project is to establish a strategy and make tangible recommendations for enhanced and efficient utilisation of geothermal energy at the southern part of the Danube Region. Various elements of a tool-box aiming sustainable management of transboundary geothermal energy resources (risk mitigation; benchmarking and a decision-tree) are tested by modelling in real environment in three cross-border pilot areas. One of the pilot areas is situated in the territory of South-east-Hungary – Western-Romania – North-Serbia (HU-SRB-RO) focusing on clastic (intergranular) geothermal aquifers of the sedimentary basin fill widely used by all 3 countries in the region, cca. 20 000 km². The city of Szeged has been facing a huge boom on geothermal usage, which means more than 10 production-reinjection doublets will be/is being installed nowadays into the deep porous geothermal reservoir. The aim of the ongoing work is to model the hydrodynamic and thermal regime of this part of the Pannonian Basin and geothermal/exploitation scenarios in the deep aquifer of the Neogene sediments - lower parts of the intergranular Upper Pannonian sequences.

Based on harmonised geological data a conceptual structural model has already been set up. The refined structural model of Szeged visualises the 3D configuration of the subsurface including an improved representation of the basement’s depth and the thickness of the thermal aquifer in the basin fill. Although the magnitude of the geothermal parameters is known from open-source databases, scientific publications, model scenes – based on the jointly collected data from the three countries – produced different thermal conductivity and heat flow values. Further modelling is being carried out to refine these values, whereas these scenarios provide information for various risk mitigation procedures and for the prediction of future adverse processes e.g. overproduction, thermal breakthrough, or cooling effects of competing usages.

The hydrodynamic and heat transport model-series have been carried out by finite-element FE-FLOW software, using different scientific approach of density-coupling (low/high degree of coupling, viscosity effect etc.) The modelling process and its logistic with the proposed methodology based on harmonised data can raise the attention on present and/or future conflicts and can reveal significant data shortages, as well as highlighting areas comprising untapped geothermal potential. This type of modelling approach of the diverse subsurface usages (e.g. geothermal, CH, CCS storage etc.) can establish the scientific basis for an integrated subsurface management.

These achievements - although based on the outcomes of the pilot area studies - will have a high potential of replicability to other areas within (and outside) the Danube Region, as they represent very common geological and geothermal settings with standard thermal water utilisation schemes.

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Session Classification: Parallel

Track Classification: Topic 5.4 - Innovative approaches for understanding groundwater flow systems
Characterizing the linkage between soil moisture dynamics and discharge at a karst region in Southwest Germany

Thursday, 26 September 2019 15:15 (15)

Karst groundwater represents an important source of drinking water for the world’s water supply. The most typical approach to characterize a karst system is the disintegration and analysis of its output signal measured at the karst spring using, for example, discharge observations, hydrochemical signal or tracer information. However, the value of soil moisture observations to identify and characterize karstic recharge processes has been receiving limited attention. In this ongoing study, we explore the usability of soil moisture observations to characterize the input signal to the aquifer, i.e. the karstic groundwater recharge dynamics. At a test site at Southwest Germany, observations of climate, soil moisture (90 profiles, at 10cm and 20cm depth, distributed across forest and grassland), and discharge are available. In order to analyze this large data set, we use an automatic routine to extract all soil moisture-discharge events. We hypothesize that recharge initiates after the saturation of the soil, which will be indicated by an increase of discharge. We express this interplay of soil moisture and discharge by hysteresis curves, which vary in shape according to precipitation characteristics, antecedent soil moisture and groundwater conditions. For some of our soil moisture profiles, we find the expected reaction: discharge initiates after soil saturation expressed by a rectangular hysteresis curve. However, at some sites, we find an almost simultaneous reaction of soil moisture and discharge or a reaction of discharge without a soil moisture increase, expressed by a flat shape of the hysteresis curve. We interpret this as the result of preferential flow that occurs close to the soil moisture profile or direct infiltration in the system. Although our analysis and data do yet not provide quantitative information on karstic recharge, it provides new insights into the spatial dynamics of the onset of karstic recharge and the importance of subsurface heterogeneity for the infiltration processes of karst systems.

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Session Classification : Parallel

Track Classification : Topic 7 - Karst Hydrogeology
Characteristics of the epiphreatic flow in the karst aquifer north from Planinsko Polje, Slovenia

Thursday, 26 September 2019 17:30 (15)

Many studies related to groundwater flow in karst aquifers are made based on observations at ponors and karst springs. Due to different limitations such as the difficulty of accessibility or a speleologically poorly investigated area, water active caves are usually not monitored.

A network of autonomous measurements in the aquifer between Planinsko Polje and springs of the Ljublanica River has been established since 2015. There, water level, temperature, and specific electrical conductivity are measured at the main ponors, springs and most of the caves with an access to the groundwater. The obtained measurements were supported by geological, speleological and meteorological data and were comprehensively analysed considering basic hydraulic principles and previously knowledge of the studied system. Interpretations were integrated by constructing conceptual hydrological models that were verified with simplified but robust numerical models.

The water level showed various dynamics, which not only resulted from the last rain event, but also from the geometry of the epiphreatic zone. Inflection points were visible in the hydrographs at almost all locations and reflected the presence of overflow channels. In addition, major geological structures have been identified to control the direction of the groundwater flow and to cause backflooding/damming of water. Temperature and conductivity measurements were used as potential tracers and enabled the calculations of transit times between consecutive points.

The developed approach turned out to be very useful to characterize the aquifer main flow dynamics. It also showed that water active caves are a very important element that should be integrated as much as possible in the observation network. Numerical models proved to be meaningful to verify qualitative interpretations made by the conceptual hydrological models. Additional improvements using a denser observation network would allow a more detailed interpretation of the system behaviour.

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Session Classification : Parallel

Track Classification : Topic 7 - Karst Hydrogeology
Submarine springs are common discharge features of karstic systems along the Mediterranean coast. In some cases, these submarine springs allow occasional seawater intrusions in the karstic aquifer causing an adverse impact on the quality of the groundwater resources. In order to manage and preserve the water resources, it is required to have a deep understanding of this phenomenon. The aim of this study is thus to characterize the hydraulic and geochemical impacts of such local and temporary saltwater intrusions on a karstic system and to determine the recovery of the aquifer.

The karstic and thermal aquifer of the Thau basin is investigated in this study since the quality of the groundwater resource has been threatened and temporarily impacted over the last 50 years by occasional saltwater intrusions (a few weeks to several months long) from the Thau lagoon through a submarine spring. The causes and impact of this process named "inversac" are not well understood.

This work is based on a comprehensive review of the last 6 saltwater intrusion episodes (from 1967 to 2014) and the integration of both historical and new hydrogeological and geochemical data.

Results show that the hydraulic perturbation is propagated instantly in the Balaruc-les-Bains peninsula and reaches a distance of about 5 kilometers upgradient within 9 days. The comparison of hydraulic heads during the 2010 and 2014 inversac episodes indicates an aggravation of the phenomenon with an increase in hydraulic head variations.

In contrast, isotopic tracers (87Sr/86Sr, water stable isotopes) and Rare Earth Elements show that the geochemical impact of these inversac events is only observed at the local scale and is still perceptible several years after the event stopped. For example, some of the thermal wells still have not recovered their initial geochemical state 20 and 40 months after the last two inversac events (2010 and 2014), suggesting a geochemical remanence of the phenomenon in the karstic system of more than 3.5 years. In addition, this study shows that the deep karstic compartment located south of the study area is not affected by the saltwater intrusion episodes and presents a different dynamic than the rest of the hydrosystem.

Overall, this work on episodic and local saltwater intrusions is a key step in understanding the dynamics of this complex karstic and thermal aquifer and will support the management of the groundwater resource.
Session Classification: Parallel

Track Classification: Topic 7 - Karst Hydrogeology
Presently, two major types of approaches to predicting the response of groundwater resources to (climate) change are available: 1) numerical models of groundwater flow and transport, 2) conceptual hydrological models. The first category is extremely data hungry and applications are time consuming, while the second relies on data-driven calibration and usually lacks adequate descriptions of the complex three-dimensional setup of the subsurface. Numerical models may be seen as the best choice to make reliable, process- and physics-based predictions. Yet, quite often, the lack of data for parameterization and calibration will hinder meaningful applications. To overcome this dilemma, we propose an alternative and complementary approach. This approach is adjusted to typical data availability of groundwater systems, but still accounts for geological conditions and their three dimensional heterogeneous distribution. The PUB (predictions in ungauged basins) concept developed in surface water hydrology was used as a conceptual basis. The fundamental hypothesis of PUB is: similar systems respond in a similar way to similar changes. Knowledge from a system with known properties and known responses can be transferred to a similar system where responses are not known (i.e. no observations exist). Adapted to groundwater, this can be formulated as: two or more groundwater systems of a certain type will show similar responses (i.e., dynamic behavior = shape of groundwater hydrographs) when exposed to similar changes (e.g. climate change). Hence, we can make predictions for places with known geology but no observations.

With the present contribution, we would like to summarize experiences we have gathered and results obtained in the attempt to test the applicability of the PUB hypothesis in groundwater. We explain the fundamental challenges involved and our respective findings so far. 1) Detection and quantification of similarity of groundwater systems. 2) Detection and quantification of similarity of groundwater hydrographs. 3) Detection of dependencies between "types" of groundwater systems and "types" of hydrographs. 4) Combining 1-3) into an approach that can be applied to predict responses of groundwater resources in places without groundwater observation wells.

This contribution is based on a number of (on-going) studies carried out at the University of Gothenburg, Sweden and University of Freiburg, Germany. Our aim with this contribution is to make the underlying ideas known to a larger audience and to invite colleagues from the groundwater community to include similarity-based approaches in their research. We have seen that similarity-based approaches have clear limitations and will not replace any of the existing methods. However, a range of examples from Central and Northern Europe show that they provide a variety of new insights and tools to investigate groundwater systems. Examples will be shown in three other contributions to this conference (Haaf et al., Giese et al., Nygren et al.).

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**Session Classification**: Parallel

**Track Classification**: Topic 5 - Tools, methods and models to study groundwater
Hydrochemical characteristics, groundwater quality assessment and environmental isotopes in M’Sila area, Hodna, Algeria

The Hodna basin located in the south-east of Algeria in the arid climatic stage, has experienced an exponential decline in its piezometric level in recent years, related to the overexploitation of the Mio-Plio-Quaternary aquifer and the impact of climate change.

Geochemistry, environmental isotopes and multivariate statistical techniques were three methods utilized for delineating the hydrogeological conceptual model of the Mio-Plio-Quaternary alluvial aquifer of the study area, in addition for defining the main factors that affect the hydrochemistry at the scale of a plain and for reconstructing the origin of groundwater and its mechanisms of recharge of groundwater.

The results of chemical analysis of 18 groundwater samples were explored by means of two multivariate statistical analysis methods: ascending hierarchical classification (AHC) and factor analysis (FA). These methodologies allowed the identification of three groups of water samples, which could represent different stages of groundwater evolution in this region. The Ca-HCO3 groundwater of type corresponds to water coming from the carbonate massifs in recharge zone in the northern part. Conversely, SO4-CI-Na groundwater type corresponds to more evolved waters, because of their proximity to a salt lake (Chott El Hodna), which naturally represents the natural outcropping of the alluvial aquifer water table.

Multivariate statistical techniques have been applied to analyze obtained on the quality of groundwater reveal the presence of three groups. Moving from upstream to downstream (North-South) we pass gradually from unsalted water to strongly salted water near the Chott. The infiltration water of group 1 mixes with all the reserves of the aquifer progressively along the underground flow up to result in a more loaded water of group 3 in the discharge zone. Nitrate concentrations could be related to agricultural activities at the lowland level. The isotopic analyzes showed a very quick recharge of the aquifer, and that the groundwater has undergone a strong evaporation in the salt lake.

The results of this study clearly demonstrate the utility of multivariate statistical analysis and isotopic analysis in hydrogeochemical studies.

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Session Classification : Poster with refreshments
Track Classification : Topic 5 - Tools, methods and models to study groundwater
Thonon-les-Bains is located in the French Alps, on the shores of Lake Geneva. The town has several groundwater resource tapping facilities at elevations ranging from 390 m to about 600 m (with a watershed elevation of up to about 1400 m). These resources differ in terms of their yield, their vulnerability to pollution, their ability to supply by gravity the whole town or only certain districts, and their long-term investment requirements.

To ensure a sustainable water supply for the town, a master plan has been developed. One of its objectives was to define an optimum groundwater resources operating scheme (defining the resources to be kept, developed or abandoned).

Within this framework, and as amortization of long-term investments has to be taken into consideration, the impact of climate change on the groundwater resources had to be assessed.

While significant developments have been made in assessing the impacts of various global economic growth scenarios on climate change, fewer works have examined the impacts of climate change on groundwater resources. This is due notably to the fact that the link between climate and groundwater resources depends on local parameters. Consequently, a long-term decrease in rainfall (depending on the global economic growth scenario considered) cannot be carried over to groundwater resources.

In the present case, a lumped groundwater model was developed using the Gardenia simulation code (BRGM) for the Blaves catchment supplying Thonon-les-bains. The model was calibrated on groundwater abstraction flow rates measured over a 6-year period using measured rainfall and potential evapotranspiration time series as input parameters. The gap between measured and simulated values was assessed in order to evaluate the reliability of the groundwater model. The IPCC Fifth Assessment Report RCP 8.5 scenario was then considered. Local monthly long-term (2070-2100) rainfall and evapotranspiration values were then used in the groundwater model. While the results showed that long-term rainfall was 21% lower on average compared to the present state, groundwater resources were estimated to be 25% lower on average (annual volume) and up to 45% lower during low-water periods. These two values (long-term average and low-water groundwater flows) were then used to develop an appropriate groundwater resources operating scheme.

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**Session Classification**: Parallel

**Track Classification**: Topic 3 - Groundwater sustainability and governance
Modeling the 3-D hydraulic conductivity distribution in the southern Po river plain by stationary and non-stationary geostatistics

Tuesday, 24 September 2019 11:15 (15)

In the last decades, numerical modeling has become one of the most important instruments to manage groundwater resources, in terms of sustainable exploitation, contamination fate assessment, and remediation scheme design and efficiency evaluation. Besides the assessment for the hydrogeological features (i.e. boundary conditions), the hydraulic conductivity (K) distribution is an important issue to be faced, especially when the considered aquifer is complex. Generally, this parameter is assigned to each hydrogeological complex, relying on values obtained by point permeability tests (e.g. pumping tests, slug tests, etc.). Although the existing calibration methods allow a good model optimization, the natural variability of the hydraulic properties cannot be reproduced in detail using deterministic and point approaches to calibration.

The main objective of the research is to draw a physically based 3-D hydraulic conductivity model by both stationary (i.e. Ordinary Kriging, OK) and non-stationary (Intrinsic Random Function theory, IRF-k) geostatistical methods, comparing them in terms of accuracy and precision. These techniques were applied to 182 Cone Penetration Test (CPT) profiles of the tip (qc) and shaft (fs) resistances, collected by the Emilia Romagna Regional Geological Survey. The obtained mechanical 3-D models, related to qc and fs variables, allowed to calculate the lithology index (Ic) 3-D model and the corresponding K 3-D model.

The selected study area is located in the southern part of the Po plain and is characterized by mainly alluvial deposits made up of undifferentiated fine silty-sandy deposits, with coarser (i.e. alluvial fans and paleo-channels) and finer (i.e. lacustrine lenses) geological bodies. These inclusions consist of gravelly alluvial fans, prevalent nearby the Apennines reliefs, sandy paleo-channels, predominant northward, and lacustrine lenses, detectable all over the area.

As a result, the OK and IRF-k method allowed to estimate the k values in a 3-D model, starting from CPT data. The obtained models reproduce as closely as possible the actual geological and hydro-geological features, not neglecting the multi-scale heterogeneity. The proposed methodological approach provides a physically based 3-D hydraulic conductivity model, with a noticeable degree of detail. Hence the models obtained can represent a useful starting point for hydrogeological modeling and/or a constraint for model calibration when the intrinsic deposit heterogeneity could affect substantially the groundwater flow and contaminant transport in the aquifer.

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Session Classification : Parallel

Track Classification : Topic 5.3 - Advanced modelling tools for subsurface hydrology.
the vadose zone to deep environments
Chemical (macro, trace - including rare earth elements) and isotopic record of deep brines leakage to shallow freshwater aquifers in northern and central Poland

Tuesday, 24 September 2019 15:30 (15)

The areas of brine leakage to freshwater aquifers were mapped with the use of over 20,000 archival chemical analyses from the data bank of the Polish Geological Institute. Such areas were named chloride anomaly zones, and were defined by groups of wells with concentration of Cl- ion in groundwater exceeding the value 60 mg/dm³ - the upper limit of the hydrogeochemical background.

The next stage of research was focused on specific chloride anomaly zones, and on intakes affected by groundwater salinization. It consisted of chemical analyses, including rare earth elements (REE) and isotopic ($\delta^{2}H$, $\delta^{18}O$) analyses of groundwater samples. The correlation of hydrochemical, geophysical and drilling data confirmed that, chlorides anomalies have been predominantly developed in geologic situations, enabling the inflow of salt waters from deeper parts of the Mesozoic complex into the shallow freshwater aquifers. These are: 1) tectonic fault and fracture zones, 2) hydrogeological windows above uplifted crests of salt anticlines and elevated tectonic blocks, 3) mature salt diapirs.

The natural process of brine migration was accelerated in some areas due to groundwater exploitation and this led to more intense mixing with fresh, drinking waters. The inflow of saline waters, ‘older’ than modern infiltration waters (supposedly diluted Mesozoic brines), into freshwater aquifers, was proved by chemical and isotopic tests ($\delta^{2}H$ and $\delta^{18}O$). Brine leakage is responsible for a significant decline in groundwater quality, which has been reported from numerous intakes working in the indicated chloride anomaly zones. This is reflected through high concentration of chlorides (>250 mg/dm³) and sodium (>200 mg/dm³) ions, in some cases associated with elevated contents of sulfate (>250 mg/dm³) and ammonium (>0,5 mg/dm³) ions. Such waters are often characterized also by elevated K, Sr, B, Mg and Ba ion concentrations.

An analysis of the content of rare earth elements (La, Ce, Pr, Nd, Sm, Eu, Gd, Tb, Dy, Ho, Er, Tm, Yb, Lu) and yttrium (REY) was used as an additional tool supporting the efforts to recognize the nature of salinization processes which have been affecting the examined freshwater aquifers. REY patterns (describing mutual relations between European Shale normalized concentrations of individual elements) were determined for the groundwater samples from selected communal intakes. Afterwards they were compared to REY patterns determined for brines samples taken from neighboring Spa or geothermal wells. In case of some wells located in area of the Baltic Sea coast, REY patterns calculated for seawater samples were also considered.

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Session Classification: Parallel

Track Classification: Topic 8 - Groundwater quality and pollution processes
HYDROGEOLOGICAL FEATURES OF THE WESTERN PO PLAIN (PIEDMONT, ITALY)

Monday, 23 September 2019 16:00 (60)

Piedmont Region, in North-Western Italy, extends for approximately 25,400 square kilometres and represents the more western part of the Po Plain. About 43% of its territory is constituted by mountains, 30% by hills while the plain covers 27% of the whole territory. The Piedmont plain is the most important water reservoir of the Region because of its size, the features of its deposits and the possibility to recharge.

A hydrogeological map of Piedmont plain (scale 1:300,000) is presented, which summarises about twenty years of research in the area. The main hydrogeological units are shown with an indication of their type and degree of permeability. The piezometric map of the shallow aquifer in plain, referred to summer 2016, is reported, highlighting the main groundwater flow directions. Other information are also presented, namely the map of depth to water table, the map of permeable deposits (0-50 m from the ground surface) and litostratigraphic cross-sections.

Moreover, time plot of piezometric level fluctuations in representative monitoring wells are provided. More specifically, monthly average piezometric level in the period 2002-2017 was analysed, describing different hydrodynamic behaviour of the groundwater table in the Piedmont Plain.

This map wants to represent an overview of the hydrogeology in Piedmont, not only for researchers but also to provide support to local authorities and professionals working on groundwater management.

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Session Classification: Poster with refreshments

Track Classification: Topic 1 - Groundwater assessment and management
Groundwater resources management has been a growing concern and scheme as the consequences of climate change and other anthropogenic forces have heavily impacted freshwater resources, especially in semi-arid regions. The adoption of managed aquifer recharge (MAR) still remain at its earliest stages of assessment in developing countries, e.g., Lebanon, where only a few studies have been conducted. Groundwater is subject to contamination and depletion due to over-exploitation, poor management, and climate change. Regional conflicts and the current refugee status have amplified the need for accessible uncontaminated freshwater resources in the semi-arid Bekaa region, where water quality is expected to deteriorate further as dry regions become drier. Thus water availability poses a challenge on sustainability. In this present work, a preliminary integrated hydrological model was constructed and calibrated using Mike SHE (DHI, 2016) for the entire Upper Litani Basin catchment at to simulate flow in steady state. Transient flow is simulated and validated based on water level observations while accounting for the different hydrological components; namely climate, river, saturated and unsaturated zone, to assess the degree of groundwater depletion, and the availability of water resources for recharge during high flow periods. It further investigates the feasibility and application of the Aquifer Storage and Recovery scheme devised for a well drilled in the Miocene semi-confined aquifer consisting of coarse alluvial deposits in the Litani Basin, Bekaa (a semi-arid region) in Lebanon, which will store surface run off during the winter, to be utilized for agricultural irrigation purposes in the summer. An experimental borehole has been drilled in the framework of a project “Strengthening Lebanese Water and Agriculture Sector” financed by the Dutch Government. The system was implemented in 2017-2018, in order to maximize well yield efficiency and reduce groundwater depletion and overexploitation. The components of the MAR system consists of a water intake reservoir and pipeline system housed in an operating container securing infiltration to and abstraction from the installed well. The small scale subsurface characterization of aquifer properties was done using grain size analysis of borehole cuttings and several pumping tests to assess transmissivity in the recharged aquifer at the borehole scale. The model will serve as an integrated decision support tool to predict the change in groundwater levels in the future under climate change scenarios and to ensure proper sustainable water management.

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**Session Classification**: Poster with refreshments

**Track Classification**: Topic 1 - Groundwater assessment and management
The mapping and characterisation of sand and gravel aquifers across Ireland; recently completed and proposed future work

The first phase of the ‘Groundwater 3D’ (GW3D) project was a government funded, multi-annual endeavour, focussed on assisting Geological Survey Ireland meet its policy goals in the areas of characterisation of and research into groundwater resources, within a number of specific themes. The investigation of the geometry of sand and gravel deposits throughout Ireland, as both a water resource and a flow pathway, was one of the priority themes identified for pursuance. The output of a previously collated national sand and gravel aquifer map, comprising 93 sand and gravel aquifer bodies, was variable, due to the inconsistent amounts of information available to delineate each aquifer body. 'Full' Quaternary stratigraphic mapping, showing the three-dimensional extent of these sand and gravel deposits, had not been completed for the majority of these areas across the country. Such mapping and subsequent characterisation was undertaken in phase I of GW3D to provide field evidence on the true nature of these deposits (i.e. thickness, saturated thickness, depth to bedrock, depth to water table, degree of grading and bedding, lateral extent and variability), in the third dimension. Thus, as well as mapping the extent and depth of the deposits, the investigations considered their hydraulic properties. A consistent, systematic approach was developed which led to the investigation of 420 discrete deposits of sand and gravels nationwide; of these approximately 200 aquifers were delineated or further characterised. Dissemination of the work is achieved through online publishing of the revised aquifer maps on the Geological Survey Ireland website with an accompanying bespoke report for each aquifer.

Geological Survey Ireland is currently moving in the direction of providing three-dimensional sub-surface models, focusing on applying sound geological science to meet the requirements of end users. Phase 2 of ‘GW3D’ will be a direct progression of phase 1, focussing on further investigating of the hydraulic properties of the aquifers and developing sand and gravel aquifer models. It is envisaged these models will help to undertake and facilitate the management of resources (such as wholesome drinking water supplies) and the environment (such as applied data provision for integrated catchment management). At the commencement of phase 2 a systematic approach to the investigations has recently been developed, using geographically-distributed case studies. The detailed hydrogeological investigation of the Robertstown Sand and Gravel Aquifer in Co. Kildare is one such case study. This project will use groundwater modelling software (MODFLOW) in order to better understand the geometry of the aquifer, the water resources it holds, and the effect of groundwater abstraction on the stability of a nearby canal.

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Session Classification : Parallel

Track Classification : Topic 5 - Tools, methods and models to study groundwater
Hydrogeological conceptual model of andesitic stratovolcanoes. The Bromo-Tengger case-study (Indonesia)

Monday, 23 September 2019 18:00 (15)

Andesitic volcanic aquifers are an important source for water supply in many countries of the world, particularly in subduction zones, such as Indonesia. Their sustainable management requires a thorough understanding of their hydrogeology. Given their complexity, multidisciplinary approaches are required and were implemented on the northern flank of the Bromo-Tengger volcano, Java Island, a 2700 m high strato-volcano, 40 km in diameter, comprising geological, hydrometeorological, hydrodynamical, hydrochemical, temperature and isotopic measurements.

Two main hydrogeological units are unveiled:

(I) An upstream volcanic unit mostly composed of a more than 1500 m thick lava flows series, Quaternary in age, topped by more recent pyroclastites up to several hundred meters thick. Despite the geological complexity of these formations in the detail, it hydrogeologically appears as homogeneous and permeable at the scale of the whole northern flank of the volcano. It hosts an unconfined aquifer, similar to a "basal aquifer" described in shield volcanoes. Some local perched aquifers (on ash layers and cooked paleo-soils) feed a few low discharge springs (few L/s). Quantitative isotopic modeling, confirmed by thermal modeling to account for the "cold anomalies" observed downstream in the aquifer, demonstrates that aquifer recharge occurs on the whole Northern flank of the volcano. Recharge spatial distribution is mostly driven by the rainfall pattern, peaking around 4000 mm/y at about 1200 m amsl, and the area of the volcano's flank that decreases with elevation.

(II) A more than 300 m thick downstream multilayer volcano-sedimentary unit, which roof extends up to about 50 m amsl, composed of coarse to fine volcanic sands, with a transmissivity ranging between 10-2 and 10-4 m2/s, interstratified with ashfalls, lahars and tuffs. It is confined by superficial decametric thick clayey layers and bounded to the North by distal clayey deposits. No geological limits were found West and East, as this aquifer gathers with the ones of neighbor volcanoes; then, for modelling purpose its hydrogeological limits were set-up based on groundwater flow lines. This geological unit hosts a confined aquifer, artesian in most places, exclusively fed by the upstream unit. Groundwater outflows correspond to (i) high discharge artesian springs (total discharge of about 4000 l/s and 3500 L/s for the Umbulan spring alone), (ii) more than 600 artesian wells (total discharge of about 2400 L/s), and (iii) vertical leakage estimated to about 600 l/s. Hydrochemistry and water dating demonstrate a South-North groundwater aging, accentuated in the downstream distal part of the confined aquifer due to artesian wells development during the last few decades. This research unveiled the conceptual model of this aquifer and, more largely, of such type of andesitic volcanic and volcano-sedimentary aquifers. It also enabled its hydrogeological modeling, and the building-up of sustainable groundwater management scenarios.

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**Session Classification**: Parallel

**Track Classification**: Topic 5 - Tools, methods and models to study groundwater
Groundwater for water scarcity regions - how to delineate the most necessitous areas? Case study for Slovakia

Lack of drinking water and water scarcity in general is at present enhanced by climate change impact. It is namely felt by people in those areas of the Slovak Republic where their own natural groundwater resources are limited by geological settings. In 2018, a regional hydrogeological research project was approved in the country, targeting those areas that are the most deficient in terms of groundwater resources so far. The aim is to help the inhabitants of regions critically threatened by water shortages to face the impact of climate change. The way in which the most deficient territories within the state are to be objectively determined is based on the history of the previous balancing of water resources and hydrogeological surveys that have been carried out in the country since the 1960s.

Since 1975, regional determination of natural groundwater resources and available/utilizable groundwater resources is carried out for territorial “hydrogeological units”. These are geographically, geologically, hydrogeologically and geomorphologically defined territorial units, specially delineated for the purposes of groundwater balancing. In Slovakia, 141 such hydrogeological units were defined at that time.

The size of total natural groundwater resources at national average is currently estimated to be about 3.0 l/s/km² in terms of specific groundwater runoff. However, as a result of environmental, technical and geological reasons combination, such a quantity cannot be sustainably used. Therefore, utilisable groundwater resources are legally defined as that part of natural groundwater resources, which can be exploited by the use of technical means (such as wells, spring sinks, drains…) on a long-term basis. Accurate calculations of utilisable groundwater resources are subjected to critical review by the Groundwater Approval Commission on the Ministry of Environment. Currently, available/utilizable groundwater resources are estimated to be approximately 55% of the total natural resources.

Approximately 83% of all available groundwater quantities in Slovakia come from 36 hydrogeological units: those where extensive accumulations of Quaternary gravelly sediments in large river valleys are found, or those formed by karstifying Triassic limestones and dolomites. Such hydrogeological units occupy 44.7% of the whole country area; second-class groundwater resources suitable only for local water supply are found in the rest of the country.

The balance sheet of utilised and utilisable groundwater resources in hydrogeological units is annually published in the Groundwater Balance Yearbook (by Slovak Hydrometeorological Institute). The spatial distribution of available groundwater resources and demands for its use is based on data collection from about 18,000 water abstraction points. For many years, the greatest unmet need of water resources in comparison to available groundwater amounts is felt in the southernmost part of central Slovakia, area mostly built by marine Miocene sediments. Therefore, the currently implemented hydrogeological surveys funded by EU cohesion funds were targeted into these areas.

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Session Classification : Parallel

Track Classification : Topic 3 - Groundwater sustainability and governance
Characterization of carbon in the shallow alluvial groundwater system

Tuesday, 24 September 2019 15:45 (15)

In the last few years, environmental pollution has been major concern in Croatia. In some parts of Croatia, uncontrolled and extensive production is causing the pollution of groundwater with nitrates, nitrate, ammonium, oils, phenols etc. An example of area with groundwater quality problems is the surrounding area of the town Varaždin. The area is densely populated and industrial and agricultural production are well developed. Because of high concentrations of nitrates, ammonium, oils and phenols, one pumping site is shut down. Since problems relating to high nitrate concentrations occurred in the research area, intensive research of source, distribution and fate of nitrogen and carbon have been carried on. Carbon has been studied because it is present in molecules that are integral to all living creatures, as carbon dioxide and methane in the atmosphere, in carbonate rocks in the lithosphere and as organic molecules in soils and sediments that are derived from formerly living material and it can be used to determine the source of the pollution. For the research purposes, a monitoring network has been established. Water samples have been taken from 10 observation wells and 4 surface water locations (river, stream, gravel pit and lake) on monthly basis. Prior to sampling, electrical conductivity, pH, temperature and dissolved oxygen content are determined by using portable WTW probes. Groundwater and surface water samples are being collected for various analyses: major cations and anions, REE, stable isotopes D, 18O and 13C , stable isotopes 18O and 15N in nitrate and nutrients (nitrate, nitrite, ammonia, phosphate, TN, TOC, DOC and TIC). In addition, soil sampling under various vegetation cycle and from different land use plots were collected. Soil’s mineralogy, especially clay minerals, chemical properties and nutrients content (organic and inorganic carbon and total nitrogen) were measured. Preliminary results showed that concentrations of TOC are almost equal to DOC concentrations in ground and surface waters. The higher concentrations of TOC and DOC are observed in surface water than in groundwater. The highest values are measured in the water of the gravel pit. According 13C ratio, gravel pit and lake waters are distinguished from ground and stream/river waters. Soil samples in the orchards contains the highest concentration of the organic carbon wail the lowest are measured in soil samples taken from cornfield.

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Session Classification : Parallel

Track Classification : Topic 8 - Groundwater quality and pollution processes
Preparing for an advanced pump/injection test in a coastal area in the Netherlands: determination of background variations and local response of groundwater heads to tide, precipitation, evaporation, and surface water levels

The Geological Survey of the Netherlands (TNO-GSN) provides public information on the subsurface (http://www.dinoloket.nl). Among this information are (hydro)geological models with hydraulic parametrization. GeoTOP is a voxel model of the upper 50 meters with voxels of 100m x 100m x 0.5m. The basis of the hydraulic parametrization is a large collection of laboratory measurements of the hydraulic conductivity determined for samples from undisturbed cores, which TNO-GSN collects systematically throughout the Netherlands. The values are upscaled from laboratory to voxel scale for each combination of geological unit and lithoclass.

In order to further test and improve the upsampling, TNO-GSN is preparing a field test focussing on the resistance of a basal Holocene clay layer. The field test will consist of pumping from the aquifer below the clay layer combined with infiltration in various infiltration wells, high frequency registration of heads in 23 piezometers, and determination of (the variation of) flow velocities over the thickness of the pumped aquifer. Nine months before the start of the field test, existing piezometers around the site have been equipped with automatic pressure transducers. These record the groundwater heads above and below the clay layer with high frequency in order to determine background variations of the head due to the tide, precipitation and evaporation as well as surface water levels. The measurements will be continued at least until the field test is fully completed.

Exploratory model simulations have shown that 1) a reliable estimate of the resistance requires the measurement of a drawdown above the clay layer, and 2) only a small drawdown will develop above the clay layer even though the pumping will run for several months. This means that a small drawdown due to the pumping has to be separated from the background influences. This is already important during the execution of the field test in order to be able to optimize the pumping. For this purpose, detailed time series modelling of the groundwater heads from the existing piezometers is carried out. Challenges in this modelling are 1) the different time scales of the tide, precipitation, evaporation, and surface water level changes, 2) the inhomogeneity of the time series with years of bi-monthly manual measurements and 9 months of pressure transducer data with 15 minute intervals, and 3) non-linearity in the precipitation and evaporation response due to drainage and the unsaturated zone.

Although, time series modelling is not the appropriate tool for the interpretation of the aquitard resistance from the field test, it is valuable because the time series models can determine the background variations of the groundwater head and allow to check the performance of the test and to tune the pumping.

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**Session Classification:** Poster with refreshments

**Track Classification:** Topic 5 - Tools, methods and models to study groundwater
Deep Coastal Aquifers - Case Studies in Tanzania and Somalia

Monday, 23 September 2019 15:15 (15)

There is no quick fix to the global water supply situation. Incidentally, an abundance of fresh water may exist right under our eyes, more specifically in deep coastal aquifers and in submarine aquifers extending far out under the salty oceans. The Kimbiji Aquifer in Tanzania, which extends some 65 km under the Indian Ocean, was discovered in 2005 by Ruden AS Geosolutions. This aquifer is presently being developed to sustain some 1.5 million subscribers of the greater Dar es Salaam area, Tanzania. We believe that the exploration methods used in Tanzania may be applied to the coasts of most of the world’s continents. We have developed a search model based on the principle that the presence of deep coastal freshwater aquifers is probable if:

1. Adequate recharge and relief exists in the coastal hinterland
2. Transmissive formations with adequate structural control exists between the recharge areas and the coast
3. Large permeable reservoirs are present along the passive margin on the continental shelf

We have looked into the water potential of Somalia based on this search model. Virtually all groundwater in Somalia originates from the mountainous Amhar region of eastern Ethiopia. These highlands capture much of the monsoon rains (June to September). The rainwater runoff feeds the Juba and Shebele drainage systems, flowing eastwards through the entire 1000 km of Somalia, towards the Indian Ocean. A proportion of the water infiltrates into underlying aquifers at or near the recharge area. On its way to the coast, the shallow groundwater becomes increasingly separated from the deep underlying aquifers. Meanwhile, a significant portion of the recharged water from the western boundary region is being conveyed along tectonic features such as faults, fractures and karst. The presence of carbonate formations suggests that karst development may be an important feature of groundwater movement in the region. Storage of deep groundwater also occurs in sedimentary basins which serve as reservoirs. There are four principal sedimentary basins in Somalia, and these will be studied in more detail during the next phase of a proposed project.

With the possible exception of the Mediterranean coastline of North Africa, the coastal areas of the African continent display a geological architecture typical of passive margins. In other words, approximately 20,000 km of the African coastline offer the potential for groundwater resources similar to (or possibly better than-) the Kimbiji reference site.

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Track Classification : Topic 5 - Tools, methods and models to study groundwater
Preliminary Studies on Regional Groundwater Management System in China

Groundwater management is a traditional and important work of water resources management sectors. Recently, China government paid much more attention on groundwater protection and restoration. As the implement of the South-to-North Water Transfer (SNWT) Project, which is carried out to channel 44.8 billion m³ of fresh water annually from the Yangtze River in southern China to the more arid and industrialized north. The North China Plain, a major groundwater overexploitation area, have been beneficial for the national action plan of groundwater protection. In responses to implement of control and management of groundwater overexploitation in China, regional groundwater management system is of great importance to analyze and evaluate the effectiveness of the plan. In this situation, a framework of regional groundwater management system was created, and the database norm of groundwater management model was established on the basis of the correlative and available groundwater data such as meteorological data, streamflow gauging station, observation wells, GRACE data, MODIS data, groundwater withdrawals and hydrogeology parameters. The database is constructed with SQL Server, and two systems are developed, which are data reporting system based on B/S framework and groundwater analysis model system based on C/S framework. The main tools in the model include correlative models (statistical model and BP model) between groundwater withdrawals, groundwater level and precipitation, the assessment tool for groundwater restoration, and numerical groundwater model. The system is applied in the North China Plain and Handan of Hebei Provinces, China. The regional groundwater management system can be served as an analytical powerful tool to the change of groundwater level, and then its relationship with groundwater exploitation at local and regional scales.

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Session Classification : Poster with refreshments
Track Classification : Topic 5.4 - Innovative approaches for understanding groundwater flow systems

Tuesday, 24 September 2019 16:00 (60)

The difficulties in the understanding and management of hydrogeological systems dominated by groundwater flow with variable density such as hypersaline lakes are further complicated. In these wetlands, the brine is located above. There, the relatively freshwater of the aquifer produces a gravitational instability that can generate convection cells. When the density differences between both fluids are sufficiently high, solute transport is the result not only of advection and diffusion-dispersion, but also of mixed convective flows. Pétrola Lake is one of the most representative examples of hypersaline wetland in southern Europe. Its environmental importance is intimately associated with the hydrogeological functioning of the system. Regional groundwater flow is radial and centripetal from the boundaries of the basin to the lake. In Pétrola Lake, surface water density reached values up to 1.29 g cm\(^{-3}\). In contrast, most of groundwater samples showed density values of 1.00 cm\(^{-3}\). As a result of the difference in density between the lake and fresh groundwater, a density-driven flow (DDF) towards the underlying aquifer is produced in the lake-aquifer interface. The electrical resistivity tomography has clearly demonstrated the intrusion of saltwater wedges in the aquifer. This information is spatially guaranteed through the mathematical modeling of the groundwater flow (2D) under conditions of variable density. The results of the simulation have served to reinforce the conceptual model of the study area, improving our knowledge about the behavior and morphology of the freshwater-salt water interface. The convective flow driven by the density difference is affected to its see by the presence of clayey levels of low permeability present at about 15-20 meters below the saline lake.

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Session Classification : Poster with refreshments

Track Classification : Topic 6 - Groundwater, wetlands and natural heritage
Combining long term monitoring of distributed temperature and cross-hole ERT with hydraulic tests to characterize the seawater intrusion and SGD dynamics in a coastal aquifers.

Thursday, 26 September 2019 15:15 (15)

Understanding the behaviour of the saline water interface and its hydrodynamics is a key issue to characterize submarine groundwater discharge and manage groundwater resources in coastal aquifers. With the objective of testing, comparing and combining different methods of monitoring and characterization, an experimental site was constructed in 2015 in the near shore part of an alluvial aquifer situated north from Barcelona city (Spain). The site, located between 30 and 90 m from the seashore, comprises 16 shallow piezometers organized in nests of three (2 m screened each) with depths ranging from 15 and 25 m and 4 stand-alone piezometers. The deepest piezometers of each nest and the stand-alone piezometers are equipped with electrodes every 75 cm in order to perform cross-hole electrical resistivity tomography (CHERT). All piezometers are equipped with Fiber Optic cable to perform Distributed Temperature Sensing (FO-DTS). Two Fiber Optic cable lines of nearby 600 m length each were installed around all boreholes with a spatial resolution of 1 m. These two techniques allowed to monitor at a great detail the solutes and thermal response from the seawater intrusion to changes in the boundary conditions. Additionally, hydraulic characterization of the site was carried out through pumping test, slug test and tide response analysis. In this work, we combine hydraulic testing information with more than a year data on electrical conductivity and temperature, to identify different dynamics of the seawater intrusion with implications for the interface distribution and the submarine groundwater discharge. The data shows different temporal and spatial scales behaviours of the seawater intrusion, related to seasonal variations and aquifer response to short-term events such as heavy rains and storm surges. Combination of the different methods allowed enhanced understanding of the processes driving seawater intrusion dynamics and submarine groundwater discharge.

Key words: coastal aquifers, monitoring, geophysical methods, FO-DTS, CHERT, SGD,

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Saline lakes are common features of arid and semi-arid regions, where the excess of evaporation over precipitation resulted in the accumulation of salts at the land surface. Among them, terminal saline lakes represent the end-point of groundwater flow systems, where water contribution derives from regional groundwater flow (RGF) as well as from perimeter recharge areas. Terminal lakes may be responsible for increasing the salinity of the shallow groundwater, due to the formation of wedge-shaped high salinity zones underneath these terminal saline lakes. Simultaneously, solutes can be transported by the density-driven flow (DDF) from the saline lake to the freshwater-saltwater interface, where they can exert an important role in the natural attenuation of pollutants. Therefore, a deeper understanding of surface-water/groundwater interaction in saline lakes is essential to know how the transport of solutes occurs. For this purpose, stable isotopes of the water molecule (δ18O H2O and δDH2O) have been widely used as tracers to provide information about hydrogeological processes. In lakes, the isotopic composition of surface water is closely connected to climate, reflecting meteorological conditions of the region, but also to the balance between inputs and outputs.

In this context, Pétrola Lake is a terminal saline lake located in the discharge zone of an endorheic basin in La Mancha region (High Segura Basin, SE Spain), an important area of distribution of saline lakes in the Iberian Peninsula. The anthropogenic pressure (agriculture and wastewater spills) over this saline wetland modifies the mass balance and the intensity of biogeochemical processes. The purpose of this work was to evaluate the interaction between groundwater and saline water from Pétrola Lake in order to improve the knowledge of groundwater recharge processes by DDF in terminal lakes. To reach this goal, hydrochemical (chloride concentration) and stable isotope (δ18O and δDH2O) data were used.

The isotopic composition (δ18O H2O and δDH2O) of 190 groundwater and surface water samples collected between September 2008 and July 2015 were determined. The results showed that groundwater recharge in the basin is mainly produced by Atlantic-derived precipitation. Moreover, data provided a regression line (δDH2O = 5.0·δ18O – 14.3‰, R2 = 0.95) consistent with dominant evaporation processes. Isotope data from lake samples suggested that the loss of water occurred at humidity values between 60% and 75%. Then, a saline boundary layer is formed, producing a leakage from the lake to the underlying aquifer by means of the DDF. The findings reported in this study has provided a deeper insight into groundwater recharge processes by DDF in terminal saline lakes using stable isotopes.

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Session Classification: Poster with refreshments

Track Classification: Topic 6 - Groundwater, wetlands and natural heritage
Assessing the groundwater potential of upper and middle aquifers in the Senegalese groundnut basin region – contribution of a numerical model

Monday, 23 September 2019 12:30 (15)

Drinking water supplies in the groundnut basin region of Senegal are mainly derived from Maastrichtian confined aquifer abstraction. However, water quality in this part of the aquifer is problematic with regard to health issue due to relatively high salinity and fluoride at levels exceeding WHO standards. From this fact, Water authority (Senegalese Ministry of Water Resources DGPRE) has decided to explore the potential of upper and middle aquifers (Quaternary, Eocene and Paleocene formations) where little is known about these hydrosystems. DGPRE hence launched a study to investigate the potential of the aquifer system overlying the saline Maastrichtian aquifer in order to build catchment facilities and/or explore dilution options to supply water that meets quality standards to this large regional population.

Field investigations including geophysical, hydrogeological, hydrochemical surveys were carried out focusing mainly on the aquifer system above the Maastrichtian formations. Results indicate moderately permeable but thick formations as well as variations in water quality from one sector to another. These investigations also reveal endorheic piezometric depressions, with a water level dropping to 30 m below sea level. This piezometric depression phenomenon is known in the Sahelian region and can be explained by several hypotheses including deep evaporation or ancient changes in sea level.

The presence of brackish water relics and piezometric depressions near the hypersaline waters of the Saloum River has raised concerns regarding the sustainability of water abstraction from these aquifers.

A numerical model was developed to serve as a tool for evaluating and managing this resource and for planning purposes. Various pumping scenarios were tested, in particular transferring the present water abstraction from the Maastrichtian aquifer to both upper and middle aquifers. The drawdown caused by pumping and the risk of water quality deterioration due to the migration of brackish water were evaluated in the long term. Results showed that exploiting this resource could be a pertinent solution. However, this would require preliminary field testing and increased monitoring of changes in salt concentrations during operation.

The combination of investigations, data analysis and numerical simulations made it possible to identify favorable locations for the creation of new shallow well fields. This work must be followed by pilot site tests, in order to verify in situ variations of the water table induced by pumping operations. If these tests confirm the potential of the upper and middle aquifers, it should then be possible to diversify resources tapped for drinking water supplies and thus improve the quality of distributed water.

The IDEV-Artelia consortium is grateful to the Senegalese Ministry of Water Resources (DGPRE) and its director, Mr Niokhor NDOUR for having accompanied the study and for his contribution to its success.

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Session Classification: Parallel

Track Classification: Topic 2 - Groundwater and climate change

Tuesday, 24 September 2019 16:00 (60)

The quantification of water inputs and outputs in closed basins is essential to obtain chemical, energy and water balances. In the case of saline endorheic wetlands, its environmental importance is intimately associated with its hydrological regime and the chemical characteristics of its waters. The endorheic basin of the Laguna de Pétrola is an example of closed basin where evaporitic enrichment of dissolved salts transported to the lake by surface water and groundwater. In this work a first quantitative approximation to water balance in groundwater discharge in Pétrola Lake for the hydrological year 2008/2009 is carried out (only year of the last 10 in which the lake was dry at the beginning and end of the period). For this, meteorological, groundwater and remotely sensed data have been used. The analysis was based on GIS operations. The hydrogeological balance elements of the endorheic basin and the lake were quantified separately. Based on the fact that the hydrological year begins with the lake completely dry, it has undergone a filling-emptying cycle throughout the studied period. The maximum volume of stored water is reached at the beginning of May (0.78 hm³), which corresponds to an estimated flooded area of 1.32 km². Since then there has been a decrease in the surface area to minimum values (dry) at the end of September. The quantitative analysis of the components of the water balance revealed that the main source of inputs to the lake is the groundwater and surface runoff, almost double the direct contributions of precipitation. In general, the evaporation rate decreases with the increase in salinity. The annual values of evaporation in the lake for mean water salinity of 60 g/L TDS can reach 1.66 hm³. These values, together with the outputs resulting from the evapotranspiration of the surrounding vegetation, only represent 70% of the water inputs to the wetland. This would suppose a positive water balance that contrasts with the evolution of the surface of water in the lake. The volume of water that is missing is interpreted as being lost by leakage due to the effect of density-driven flow (DDF). The water of the lake has a density that can reach 1.29 g cm⁻³. However, the groundwater of the aquifer that feeds the lake has density values of 1.00 g cm⁻³. As a result of the difference in density between the lake’s brine and the fresh groundwater, there is a DDF to the aquifer that can account for a considerable percentage of the lake’s water outflows, up to 0.64 hm³.

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Session Classification: Poster with refreshments

Track Classification: Topic 6 - Groundwater, wetlands and natural heritage
Baseline hydrogeochemical characterisation of a vulnerable pristine high-mountain karst aquifer in the southeastern Pyrenees

Thursday, 26 September 2019 16:00 (60)

KEYWORDS: Alpine watershed, Karst aquifer, Spring discharge, Precipitation, Hydrogeochemistry, Isotope hydrology

High mountain karst aquifers located in pristine zones are often an important source of water supply downstream. These hydrological systems with typically short transit times are very vulnerable and there is a general consensus regarding the necessity of their protection. Despite that, most of these high-mountain hydrogeological systems are not sufficiently characterized neither well understood.

From the perspective of climate change impact on groundwater resources, karst aquifers located in the drought-prone Mediterranean areas are currently on the focus of research. The predicted scenarios of both an increasing of temperatures and a decreasing of precipitations may likely impact aquifers recharge. In this regard, a baseline hydrogeochemical characterization of these high mountain aquifers is the first step to understand their hydrological behavior, and therefore adapting to climate change in relation to groundwater resources.

This research is focused on the Port del Comte (PC) carbonate massif, which is located in the southernmost part of the Catalan Pyrenees (northeastern Spain). The elevation of the massif ranges from 900 to 2387 m a.s.l, and it covers an area of approximately 110 km2. The PC constitutes an independent structural and regional hydro-geological unit, and contains one of the most important karst aquifers of the Catalan Pyrenees, formed by Lower Eocene – fissured and karstified limestones and dolomites. No previous studies regarding the geochemical and isotopic groundwater baseline characterization of this aquifer are available. This work presents the results of the groundwater and precipitation sampling campaigns conducted during the period Oct 2013 – Oct 2015. A total of 43 springs were visited for groundwater sampling twice per year (i.e. before snowfall and after snowmelt seasons). The hydrogeochemical evolution of groundwater is specifically studied in six karst springs, which were regularly sampled every three to four weeks. In all cases, the “in-situ” physico-chemical parameters (pH, EC, T, redox, alkalinity, TDS) were measured. The geochemical analysis considered major ion and trace elements and isotopic composition ($\delta$2H,H2O, $\delta$18O,H2O, $\delta$34S,SO4, $\delta$18O,SO4, $\delta$15N,NO3, $\delta$18O,NO3) of spring groundwater and precipitation ($\delta$2H,H2O, $\delta$18O,H2O). The hydrogeochemical facies of the sampled waters range from low mineralized Ca-HCO3 waters to Ca-SO4 and Na–Cl water types. Results are discussed in terms of the spatio-temporal variations in the hydrogeochemical characteristics.

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Session Classification: Poster with refreshments

Track Classification: Topic 7 - Karst Hydrogeology
Data worth in models of groundwater contaminant fractionation

Thursday, 26 September 2019 15:45 (15)

In hydrogeology and in the geosciences in general, quantification of uncertainty is just as crucial as parameter estimation when using models to make assessments and decisions. Moreover, understanding the relative value of individual measurements and of measurement types enables more effective and targeted decision-making when planning acquisition of additional field data. This analysis of data worth is even more impactful when one considers novel types of measurements or novel problems that involve multiple coupled physical or chemical processes.

Here, we introduce and employ a novel software interface COMPEST to investigate data worth and uncertainty related to groundwater contaminant fate. COMPEST is a compact and open-source program that functions as a user-friendly interface between the multiphysics modelling package, COMSOL, and the parameter estimation package, PEST. This modelling framework allows for the numerical treatment of an extremely broad range of inverse problems involving coupled processes.

The phenomenon of isotopic fractionation of chlorohydrocarbons (e.g., PCE, TCE), present as groundwater contaminants, is exemplary of the type of problem for which this modelling approach is ideally suited. Isotopic enrichment and depletion due to degradation and diffusion can be measured using compound-specific isotope analysis (CSIA). To date, research has not yet established the data worth of these measurements in informing model parameters and reducing the uncertainty of predictions. We thus seek to evaluate the worth of CSIA data in constraining models of contaminant transport and degradation. As the phenomenon of back-diffusion, wherein the contaminant diffuses from a low-permeability zone to a higher-permeability zone, causing plume persistence, is a current challenge, we focus on the aquifer-aquitard interface. Our work also includes development and implementation of novel isotopic fractionation models that take into account primary and secondary isotope effects. Our results show the utility of both the developed modelling approach and the usefulness of CSIA measurements in investigating contaminant fate.

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Session Classification : Parallel

Track Classification : Topic 5 - Tools, methods and models to study groundwater
Reassessing groundwater resources in the southern Iullemmeden Basin: Combining archival data and current monitoring.

Monday, 23 September 2019 15:15 (15)

Groundwater resources in Sub-Saharan Africa are promoted by development organisations as reliable alternatives to ensure water supply for human consumption and agricultural use. National efforts to map and monitor groundwater quality and quantity, however, are not adequate to promote sustainable groundwater management. Within a technical cooperation project, the Federal Institute for Geosciences and Natural Resources (BGR) supports the intergovernmental Niger Basin Authority (NBA) and its nine member states to establish groundwater-monitoring networks, map the quality and quantity of the groundwater resources, and elaborate tools for groundwater management.

The paper presents a reassessment of the groundwater resources of the southern Iullemmeden Basin derived from the combination of archival data and recent measurements within the AGES monitoring network. To improve the limited coverage of national databases, the technical cooperation project strives towards the valorization of so-far neglected grey literature and archival data including, among others, the groundwater appraisals of the mid-20th century as well as available reports of (inter-) national development projects.

A major challenge for the harmonization process is the differentiation of the multi-layered aquifer system of the Iullemmeden and the assignments of wells to one of the aquifer storeys of the Continental Terminal (Ct1-3) and the Continental Intercalaire/Hamadien. Unreliable lithological and technical profiles together with the usual tapping of multiple aquifer storeys to increase productivity limit the use of both archival and contemporary measurement data for the characterization of defined groundwater levels.

To create a consistent conceptual (hydro-)geological model, a general reassessment/revision of borehole lithology and stratigraphy became necessary. We explore the geostatistical approaches to discriminate groundwater bodies based on water chemistry, hydraulic head, and isotope data to improve the original lithostratigraphic classification.

Valorization of archival data – with the respective thorough quality checks – is underestimated provides necessary baseline data for groundwater management.

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Session Classification : Parallel

Track Classification : Topic 1 - Groundwater assessment and management
Assessing the potential impacts of shale gas development on shallow aquifers through upward fluid migration: A multi-disciplinary approach applied to two areas in eastern Canada

In eastern Canada and northeastern U.S.A, several jurisdictions have decreed moratoria on hydraulic fracturing due to public concerns regarding its potential environmental impacts, particularly on shallow groundwater resources. The Geological Survey of Canada has carried out two projects to assess the potential for fluid migration from deep (~2 km) hydrocarbon-rich shale or tight sandstone units to shallow aquifers (Saint-Édouard area, Quebec and Sussex area, New Brunswick). In both areas, regional faults are present and dissolved hydrocarbons gas have been found in shallow groundwater. However, the geological and hydrogeological contexts of the two study areas are very different. Also, while the gas field near Sussex has been in production since 2001, no gas well has been in production in southern Quebec.

In these two study areas, as in most regions around the world, the intermediate zone (IZ) located between shallow aquifers and deep hydrocarbon reservoirs has been overlooked, despite the fact that this IZ controls the vulnerability of shallow aquifers to industrial activities at depth. Due to this lack of data, these projects had to rely mainly on multi-source indirect data for the IZ characterization.

Data collected and their interpretation provided no evidence for the presence of large-scale connections between gas reservoirs and shallow aquifers in these study areas. On the contrary, in both project areas, the IZ seems to provide an efficient barrier protecting aquifers from the potential upward migration of fluids originating from deep hydrocarbon reservoirs. This conclusion integrates results from geomechanical studies, from geophysical and geological interpretations of the structural context and from geochemical baseline studies. Nonetheless, some old saline groundwater was found locally in some of the shallow (~50 m) observation wells, but this groundwater did not contain large concentrations of thermogenic methane. This water is inferred to come from a few hundred meters below the surface and is linked with the surficial discharge of regional groundwater flow pathways.

Regular monitoring in several wells in these projects proved very helpful to ascertain the source of methane, as individual samples commonly provided ambiguous results. Monitoring has also shown that large variations in both methane concentration and isotopic composition can occur naturally. These findings demonstrate that a single sampling campaign, which is what regulations require in most cases, may lead to erroneous interpretations of gas origin and imply that monitoring should be carried out over at least 1 or 2 years prior to hydrocarbon development to establish the natural variations of both methane concentration and isotopic composition. The methodology developed during these projects should help support the regulatory process for the protection of shallow groundwater in the context of unconventional resources development.

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Session Classification: Parallel

Track Classification: Topic 8 - Groundwater quality and pollution processes
Thermal springs as „outcrops” of geofluid systems and provenance of biogeochemical accumulations and environmental impacts

Monday, 23 September 2019 16:00 (60)

Buda Thermal Karst is an exceptional natural laboratory to study the interaction of geofluid systems influenced by different driving forces such as water table differences and heat convection; and by fluids from meteoric infiltration and saline water of geological formations. Due to the elevated heat flux of the area (up to 100 mW/m²), the temperature of the fluids is influenced by advection and heat convection (Havril et al. 2016; Szijártó et al. 2019). The evolution of geofluid systems is ongoing since the late Miocene, consequently fluid systems have an outstanding effect on mobilization and accumulation of matter and heat. Thermal springs arise at the boundary of confined and unconfined part of the BTK can be handled as “outcrops” of interacting geofluid systems (Mádl-Szönyi and Tóth 2015), since they reveal the complex physical and geochemical processes of the system. At the same time, they accumulate the mobilized and transported matter at the surface in the form of carbonate and biogeochemical precipitates (Dobosy et al. 2016; Kovács-Bodor et al. 2018; Kovács-Bodor et al. 2019). The long term scientific researches of the area revealed the necessity of the approach, to handle fluids of thermal springs and their precipitates, and discharging water and its heat content; radioactivity and trace elements of precipitates and CO₂ and ²²²Rn exhalation from thermal water, in a comprehensive way. This result is part of a project that has received funding from the European Union’s Horizon 2020 research and innovation programme under grant agreement No 810980”.

References:

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Thermal springs as „outcrops” of geothermal systems

Presenter(s) : MÁDL-SZÖNYI, Judit (Associate Professor)

Session Classification : Poster with refreshments

Track Classification : Topic 5.3 - Advanced modelling tools for subsurface hydrology: from the vadose zone to deep environments
Nullspace Monte Carlo particle tracking to identify source areas of groundwater pollution in the N-W Milano FUA (AMIIGA Project-CE No 32)

Tuesday, 24 September 2019 15:30 (15)

In Functional Urban Areas, management plans need to take into consideration both point sources (PS, corresponding to areas releasing plumes of high concentrations) and multiple point sources (MPS, consisting in a series of unidentifiable small sources clustered within large areas) that cause diffuse groundwater contamination. For the former category, according to the Decree n°152/2006 in case they are suspects linked to historical analysis or evidence, if the analytical results overtake the limit concentration (1.1 µg/l for Tetrachloroethene in the italian law), the site is “potentially contaminated”.

Tools developed within the AMIIGA Project (WEBGIS, multivariate and cluster analysis) were applied in order to reconstruct the historical activity in a specific spatial and temporal context. In order to reconstruct main groundwater flow direction and advective transport of the contaminant in a pilot area in the NW part of Milano FUA, a numerical multi-layered transient model was implemented and calibrated with Modflow. Withdrawal from 4997 wells has been considered as a major source of uncertainty in contaminant directions (PEST). The deterministic approach is not able to consider the uncertainties due to calibration parameters and targets affected by data entry error.

Adopting in PEST a Nullspace Monte Carlo (NSMC) analysis, several sets of K- fields were generated, all respecting the measured transient head targets. Considering the effect of heterogeneity in K-distribution within the aquifer, using MODPATH and placing a number of particles as starting points in a suspected contamination site, 400 forward MODPATH runs were performed starting by a stochastic set generated by the NSMC and minimizing the objective function (composed by head targets in monitoring wells).

Collecting the particle positions in each cell of the multi-layered aquifer for the most suitable realizations (selection was based on acceptable threshold objective function), the stochastic forward tracking technique was able to obtain: 1) probabilistic map of source location and time of source activation 2) wells likely to be impacted downstream of suspected source and 3) correlation between time frequency of passing particles and observed concentration time-series in the suspected wells.

Identification of the sources of groundwater contamination is crucial to enable remediation of contaminates sites, where groundwater concentrations are higher than the threshold limit. Identification is always very complex and very difficult to be solved in old industrial areas where contamination can be very dated. Following a criterion of the “most probable than not”, a probabilistic methodology was developed to quantify the sources of uncertainty affecting groundwater flow over time (abstraction rate from wells and contamination spill in the area) and the uncertainties linked to hydrogeological model (K and vertical discretization). The obtained maps correlate the historically contaminated wells with the "potential source areas", thus enabling public authorities to focus their investigations of actual contamination sources.

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Session Classification : Parallel

Track Classification : Topic 10 - Urban groundwater
Hydraulic or flow connectivity is important for conceptualising flow in geological media. Despite its importance there has, however, only been one unambiguous attempt at defining it: 'the joint probability that hydraulic conductivities at any two points, separated by a given lag vector (directional distance), fall above some relatively high value' (Neuman, 2005). We suggest that whilst this definition may be appropriate to flow within a homogenous porous medium, its application to fracture systems does not account for the heterogeneous nature of flow at different scales in these systems. For example, within such systems exceedance of high hydraulic conductivities is no guarantee that two points are hydraulically connected. In this study we suggest that hydraulic connectivity in geological fractured media is investigated using all the parameters of the perturbation of a fluid, whether it be physically or chemically, and the resulting response of the fluid. In hydrogeological investigations, parameters of the perturbation could be, for example, recharge, the amount of groundwater abstracted or tracer added, while parameters of the impact could be the time until impact, the drawdown, and the direction and distance to where impact occurs. This approach is required because parameters of the perturbation and the response depend on the specific study, its geology and the investigation of hydraulic connectivity being undertaken e.g. a pumping test or a tracer test. In this talk we illustrate the importance of this approach for hydrogeological investigations and the parameterisation of flow, in systems where flow is shown to be intrinsically heterogeneous at different scales, the fractured and karstified limestones of Ireland.
Groundwater resources of the Pyrenees in the global change context – The PIRAGUA Project

Monday, 23 September 2019 16:00 (60)

The Pyrenees range is a transboundary region shared by Spain, France and Andorre whose water resources are diverse (snowmelt and rainfall runoff in a topographically variable context, groundwater in complex and heterogeneous aquifers) and poorly known. As many other mountain regions, this territory is particularly vulnerable to the impacts of climate change. The PIRAGUA project, funded by FEDER through the EU POCTEFA Program, addresses the assessment of the hydrological cycle of the Pyrenees in the context of climate change. The goals of the project are to unify and homogenize the existing information, prospect for future scenarios, develop indicators of change, and propose adaptation strategies in relation with the territory, with the ultimate goal of supporting investment aimed at adapting to climate change in relation to water resources.

In the PIRAGUA framework, the groundwater component of the hydrological cycle of the Pyrenees range is being assessed with focuses on: 1) the design of an homogenous hydrogeological database at the Pyrenean scale, 2) the groundwater recharge from precipitation estimation over the last 30 years (including comparison with different modelling methods) and 3) future recharge evolution according to climate projections downscaled on the Pyrenean scale.

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Session Classification : Poster with refreshments

Track Classification : Topic 1 - Groundwater assessment and management
Predictive groundwater flood mapping in a lowland karst environment

Thursday, 26 September 2019 12:30 (15)

Quantifying the frequency and magnitude of flood events is a key step in the management of flood risks. However, the nature of groundwater flooding on the lowland karst limestone plains of Ireland pose significant technical challenges in this respect. These areas are susceptible to groundwater flooding due to the combination of low soil and aquifer storage, high diffusivity and limited surface drainage. A sequence of extreme flood events in the past decade has highlighted the lack of understanding of groundwater flooding as a geohazard, and highlighted the need for greater understanding of the risks posed by groundwater flooding in a changing climate. A novel approach was developed to produce predictive groundwater flood maps for Ireland in line with the 2nd implementation cycle of the EU Floods Directive. A monitoring network of over 50 sites was established during to provide baseline model calibration data. These data were supplemented with water level time series derived from multi-temporal Synthetic Aperture Radar (SAR) imagery for the key 2015/2016 flood event. Hydrological models capable of reproducing groundwater flood behaviour from antecedent rainfall and soil moisture conditions were developed. Models for viable groundwater flooding locations were calibrated on a combination of observed and SAR hydrographs. Using long-term observational and stochastic meteorological series as input, the models have been used to construct long-term hydrological series suitable for extreme value analysis and the generation of predictive groundwater flood extents and maps.

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Session Classification : Parallel
Track Classification : Topic 7 - Karst Hydrogeology
Developing a real-time monitoring network of groundwater dependent karst wetlands in Ireland

Tuesday, 24 September 2019 16:00 (60)

Turloughs, a form of ephemeral groundwater-dependent wetland, are a defining feature of the limestone lowlands of Ireland. As a protected habitat under both the EU Water Framework and Habitats Directives, there is a requirement to maintain and enhance the conservation status of turloughs and to protect them from ecological degradation. However in order to achieve this we must understand the environmental processes that support turlough habitats in favourable condition. Key to this is adequate monitoring of the ephemeral groundwater flooding which defines the turlough habitat. However, a lack of appropriate monitoring infrastructure has been highlighted as a major impediment to effective habitat management. In response, Geological Survey Ireland have established a telemetric turlough monitoring network. The nature of groundwater flooding poses significant technical challenges to real-time monitoring installations; sites can be completely dry during summer months while during winter floodwaters can extend to hundreds of hectares. An exploratory network of over 50 sites were instrumented during an 18 month period to provide baseline data for the telemetric site selection process. Multi-criteria analysis was then applied to the design of the telemetric network; factors considered included hydrological regime, historic data availability, flood receptor density, ecological value and geographical representativeness. Selected sites have been instrumented with telemetric systems allowing real-time acquisition of groundwater flood data. The network is for the first time providing long-term observational data of these groundwater dependent wetlands, and in doing so taking an essential step towards their sustainable management and tackling the challenges posed by climate and global change.

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Session Classification : Poster with refreshments

Track Classification : Topic 6 - Groundwater, wetlands and natural heritage
Group Water Schemes: Where society’s needs and expectations meet

Monday, 23 September 2019 15:00 (15)

In Ireland, a Group Water Scheme (GWS) is a private, community-owned water supply. Group Water Schemes form a significant supply type outside Irish cities and large towns, with many rural communities relying on a GWS for their drinking water. Since 2013, a programme to delineate zones of contribution (ZOC) for approximately 260 groundwater supplied GWSs has been carried out across Ireland. The programme -funded through the Rural Water Programme by the Department of the Environment, Community and Local Government- is a collaboration between Geological Survey Ireland (GSI) and the National Federation of Group Water Schemes (NFGWS). The main output of the pilot project was to delineate ZOCs and highlight groundwater vulnerability within the ZOC. This enables scientifically informed decisions in relation to possible protective measures and future planning. Another fundamental aim of the project was to engage with the GWS personnel so that they would fully understand the concepts and data behind the reports, and why certain data were requested or collected (e.g., hydrochemistry, borehole logs, water levels etc.). The final element of the project was to present the information and discuss the conceptual model, recommendations and any management implications with the GWSs. Evidently an increased understanding has enabled the GWSs to have greater ownership of their supply and the decisions made about it.

Such understanding and ownership are key since the sustainability and governance of their groundwater supplies are under mounting pressure. On top of the complexities posed by Irish hydrogeological settings (e.g., karst, fractured bedrock aquifers, recharge rejection), water usage and quality are coming under increasing stress from changing population and changing land use practices. Group Water Schemes are affected by: agricultural intensification and the associated impacts from nitrates, pathogens, and pesticides; increased infrastructural development; changing demographic and social dynamics; increased housing and wastewater treatment requirements; climate change in different guises (e.g., drought, groundwater flooding, extreme weather events). The ZOC programme has helped educate GWSs about groundwater and their management options. It has provided communities with a greater understanding of their catchment and established a baseline hydrochemical database from which to operate. The programme has placed GWSs in a better position to advise stakeholders and future proof their water supplies. This paper presents case studies, outlining some of these pressures and demonstrating the benefits of this mutual collaboration.

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Session Classification : Parallel

Track Classification : Topic 3 - Groundwater sustainability and governance
Finding geothermal resources under an urban area (Barcelona)

Thursday, 26 September 2019 17:15 (15)

While drilling the Barcelona Metro L9 line, around the Fondo station of Santa Coloma de Gramenet (Barcelona), was detected that groundwater temperature was found to be up to 55°C. No previous evidences of geothermal activity were known in that area. This geothermal spot is located under a dense urban area where the study of its hydrogeological and geothermal features is limited by urbanization.

In order to overcome this problem a study has being undertaken at local and regional scale. This allows studying the feasibility of a future energy exploitation of the geothermal resource, as well as, assessing its potential for future exploitation in this dense urban area. The objective of the regional study is to understand the dynamics of the system for justifying the geothermal anomaly identified.

Many different tasks have been performed to achieve this goal, as geological assessment, borehole drilling, geophysics, etc. This anomaly is attributed to a rise of deep groundwater through some tectonic structures, in a similar way to other geothermal zones of Catalonia (Spain). Integrating many of this information into numerical models of flow and heat transport will allow validating conceptual model and quantifying these potential resources.

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Session Classification: Parallel

Track Classification: Topic 10 - Urban groundwater
With an estimated share of about 65 percent, groundwater is one of the major drinking water sources in Europe, and is often essential for irrigated agriculture. Groundwater availability can also be especially important in times of surface water scarcity when groundwater abstraction may increase to alleviate negative effects to the livelihood of people. Drought events such as in 2011-12, 2015 and 2017-18 showed spatial coherence across several European regions in surface water deficits, and are likely to affect groundwater levels in a similar pattern. However, groundwater droughts may also show distinct spatial coherence based on their hydrogeological settings and recharge patterns as much as on the driving meteorology and available recharge. To assess whether the patterns in groundwater drought propagation are similar to the observed extent of major surface water droughts, a pan-European analysis of historic groundwater level data is required. However, no such study has been undertaken to date.

To address this gap, and to evaluate spatial patterns of groundwater drought response on a continental scale from the late 1900s to present, a pan-European Groundwater Drought Initiative (GDI) was formed. Within GDI, groundwater data from numerous supporting institutions was gathered and jointly analysed, covering a spatial extent from the Iberian Peninsula to Eastern Europe (Ukraine). Thus we produced the first comprehensive overview of historic groundwater droughts across Europe. The spatio-temporal analysis is based on the Standardised Groundwater Index (SGI), which allows for comparison of sites from disparate regions in a consistent manner. Spatial patterns in the drought response across the continental scale were analysed. First insights from the study highlight differences in groundwater system responses to the driving meteorology, such as fast and slowly responding sites and their spatial coherence. Delayed responses to major surface water droughts, like the 1975-1976 or 1996-1997 events, are observed at many of the analysed sites, though impacts differ based on the specific site setting. The further processing of this data will allow for more detailed comparison of the historic groundwater droughts with major surface water drought events, and the analysis of driving factors will increase our understanding of how catchment and local characteristics impact on groundwater responses. Additionally, areas particularly vulnerable to groundwater droughts will be identified, thus allowing for improved groundwater management.

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**Session Classification :** Parallel

**Track Classification :** Topic 1 - Groundwater assessment and management
Groundwater protection zones and the security of public water supplies

Thursday, 26 September 2019 16:00 (60)

Groundwater provides a third of the drinking water in England, but the proportion rises to 80% in some densely populated areas of southern and eastern England. To protect the quality of drinking water the Environment Agency, the environmental regulator, has defined groundwater Source Protection Zones (SPZs), which show the risk of contamination from any polluting activities. The policy states that the zones are used with Groundwater Protection Policy for pollution prevention and monitoring. The zones are based on travel times to the source in the saturated aquifer, assuming a porous medium, of 50 days (SPZ1, inner zone), 300 days (SPZ2, outer zone) and the total groundwater catchment (SPZ3).

Application of this policy thus requires that the Environment Agency will normally oppose new developments in SPZ1 which involve large-scale storage of hazardous substances, e.g. a chemical works or petrol filling station, as well as cemeteries, liquid effluent disposal and some infrastructure schemes. However, it appears that this policy is not consistently applied, thus allowing some recent developments very close to strategically important groundwater abstractions. This results in potential risks for the water supply companies and ongoing dialogue on the real levels of risk, effectiveness of engineered mitigation and threats to security of public water supplies. These issues are illustrated with an example of a proposed petrol filling station within 200m of an abstraction borehole.

The borehole was drilled in 2010 to replace an existing abstraction which was causing unacceptable environmental impacts. It abstracts water from the Cretaceous Chalk, a soft, fissured white limestone, which is overlain by 20m of sand and clay. Geophysical logging showed a very large ‘tunnel-like’ fissure at 29.8 m depth with four medium aperture and numerous small fissures between 26 and 38m. Based on these observations and the regional understanding of the Chalk aquifer with convergent flow to the valleys, dissolution and self-organised permeability and flow, it is clear that the aquifer has some characteristic features of karst. Thus the equivalent porous medium approach used to define the SPZs provides inadequate protection for this source, due to the selection of an inappropriate conceptual model selection.

At this site, the Environment Agency has not opposed the development of a large petrol filling station within the defined SPZ1. Instead, the proposed approach is to allow an engineering solution to manage all the risks during construction and operation. This has raised some strategic questions about approaches to risk, the value of groundwater and the need for groundwater protection. The presentation will consider the wider implications of these aspects, as one possible interpretation is that our water supplies are of secondary importance to other elements of infrastructure, even in water-stressed regions.

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Session Classification : Poster with refreshments

Track Classification : Topic 7 - Karst Hydrogeology
Implication of geological heterogeneity on the distribution of dissolved arsenic in an alluvial aquifer in Italy evaluated using a 3D multicomponent reactive transport model

Tuesday, 24 September 2019 15:45 (15)

Millions of people are exposed to the potential risks of high arsenic (As) concentration through groundwater intake. Numerical models are powerful supporting tools for decision makers to make informed decisions that could help to minimize such risk, yet the ubiquitous presence of heterogeneity creates uncertainty in the model predictions. This is demonstrated through this presentation, which summarizes the key results of a modeling analysis using 3D multicomponent reactive transport of the shallow aquifer of Venetian Alluvial Plain (VAP). The VAP is notoriously affected by As contamination, characterized by a patchy distribution with variable extensions and concentrations, sometimes exceeding the WHO recommended limits for drinking water. Within the VAP, we focused in detail on an agricultural zone nearby the Venice lagoon, affected by As contamination (called “Aree Agricole West”, AAW). The available data, collected by several hydrogeological surveys, show a spatial and temporal variability of As concentration, which can be associated to a variety of hydro-geochemical processes such as redox variations, sorption or reductive dissolution of As-rich iron oxy-hydroxides. The 3D reactive transport model showed a strong dependence between the aforementioned processes and subsurface heterogeneity. The material distribution, indeed, plays an import role affecting the arising of the main chemical reactions. There is a clear spatial and temporal distribution of dissolved arsenic as a function of the subsurface heterogeneity. The results are explained considering strong effects of oxy-reductive potential on arsenic mobility, likely correlated to organic matter degradation. Depending on the recharge seasonality, the model suggests the uprising of reduced condition, as affected by other mechanisms such as reductive dissolution of iron hydroxides, ion exchange and sorption processes, causing arsenic mobilization. The model also suggests the importance of a detailed characterization of the site, which constrains input parameters that could otherwise create further uncertainties in the model outputs.

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Session Classification :  Parallel

Track Classification :  Topic 5.3 - Advanced modelling tools for subsurface hydrology: from the vadose zone to deep environments
Re-utilizing possibilities of abandoned hydrocarbon wells in Northern Hungary

Monday, 23 September 2019 12:15 (15)

The Research Institute of Applied Earth Sciences of the University of Miskolc, together with the Faculty of Earth Science and Engineering have been working on the PULSE project since 2016. The aim of the project is to allow Hungary’s abandoned or unproductive hydrocarbon exploration wells and drillings to work for geothermal utilization. After sorting out more than a thousand drillings into the database, they were evaluated and mapped. Then we concentrated on the Northern part of Hungary. It is important to examine which unused wells or drillings are suitable for geothermal use. So, the structure of this database serves this purpose. With the help of this work, they can serve a new goal, either through heating or electric power generation.

The results of the last research period are related to the following topics:
1. Development of data collection methodology. Collecting data for wells located in Hungary, collecting spatial data, collecting data on geological heat storage.
2. Database construction, geothermal energy recovery data analysis. The database, regional database, heat storage database.
3. Re-evaluation of wells from the aspect of heat recovery, spatial evaluation.

Our studies in the PULSE project can have a particular interest in the already designated geothermal concession areas. The project will give additive information about the geothermal situation, but also will provide better planning conditions related to re-utilized abandoned wells. Our research can also help some future projects to reduce the costs of re-utilizing abandoned hydrocarbon wells.

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Session Classification : Parallel
Track Classification: Topic 1 - Groundwater assessment and management
Divergent or distributary flow routes are frequent in karst systems, as demonstrated by numerous tracing experiments throughout the world. However, distributary flow is less common in surface systems, in which streamflow favours the convergence towards the base level. Distributary flow systems are also in contrast with the initiation and development of conduits in carbonate rocks, where flow in faster developing passages distorts the equipotential field, causing the abandonment of some routes or the convergence of channels, resulting in dendritic cave systems, the most common cave pattern. It appears thus, that distributary groundwater flow is not to be expected in natural systems, and its recurrence in karst systems requires an explanation.

Dissolutionally enlarged joints and bedding planes are the most common avenues of flow in karst systems, but as matrix permeability tends to be very low, especially in mature carbonates, flow in high permeability channels will behave as "confined" flow, in which small variations in head can result in the exploitation of alternative routes, commonly represented by nearby bedding planes or joints. This situation is favoured in carbonates in which the vertical distance between these alternative horizons is within the range of natural vertical variations in elevation of the phreatic zone. Low dipping, well-bedded carbonates, especially in situations when the dip coincides with the direction of the hydraulic gradient are especially prone to the activation of alternative routes.

The interplay between water table rise, variations in base level (thus favouring changes in the elevation of discharge zone), seasonal/episodic recharge and horizontally bedded carbonates can foster the creation of distributary routes, mostly under episodic situations, related to specific climatic conditions. Tracing under distinct recharge situations may thus be crucial in delineating the true character of groundwater flow routes in karst terrains, although in seasonal climates or under flooding scenarios, such as in many tropical areas, this implies in difficulties for access and proper monitoring.

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Session Classification : Parallel
Track Classification : Topic 7 - Karst Hydrogeology
THE ORIGIN OF GROUNDWATER AND ITS CHEMICAL COMPOSITION IN THE AZUA PLAIN, DOMINICAN REPUBLIC

Friday, 27 September 2019 11:15 (15)

Summary:
The groundwater quality of an aquifer for the different uses to which the water is destined depends on natural and anthropic processes, which must be understood to perform a sustainable use of groundwater. With the support of the International Atomic Energy Agency, hydrochemical and isotopic techniques have recently been applied in the aquifer of the Azua Plain to assess the origin of the chemical composition of groundwater, whether it is the result of natural processes or is affected by contamination, and in case of contamination what is the origin and its extension. The study focused on samples of rainwater falling on the aquifer surface (Sisal Station) and also on a higher area (Peralta Station), of rivers flowing across the Azua plain (Jura and Tábara rivers), and of groundwater. The major chemical components (Ca2+, Mg2+, Na+, K+, HCO3-, Cl-, SO42- and NO3-), stable isotopes (δ18O,H2O, δ2H,H2O, δ13CDIC, δ15NNO3 and δ18ONO3) and radioactive isotopes (3H, 14C) were considered. The main results show that in the municipality of Azua the waters are contemporary, while in the municipalities of Estebanía and Las Charcas the waters are also young but somewhat less. The chemical composition of part of the groundwater samples studied is of natural origin, and is mainly due to dissolution of carbonates and to cation exchange. But part of the aquifer is affected by pollution of mainly agricultural origin. A conceptual model of aquifer contamination, the identification of pollution sources and natural attenuation processes has been established through the interpretation of isotope nitrate data.

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Session Classification: Parallel

Track Classification: Topic 9 - Groundwater and socio-economic development in Latin-America
Hydrological changes in representative ponds at Doñana National Park (DNP) southern Spain, from 1994 to 2015

Tuesday, 24 September 2019 16:00 (60)

Changes in the flooded surface, groundwater levels and rainfall data have been analysed in eight ponds of DNP from 1994 to 2015. In addition, a Hydrological Function Index (HFI), that relates morphological and climatic variables, was calculated for the ponds and subsequently compared. Results showed that precipitation was 10% lower during the second half of the study period (2006 - 2015). We used precipitation as a proxy of water inputs to the ponds (via both direct rainfall and groundwater discharge). A consequent and proportional reduction in the average flooded surface (i.e. a reduction of 10% or less) was detected in 3 out of 8 ponds studied. On the rest of the ponds, reductions of the flooded surface ranging from 35% to 97% were measured. The average depth of the water level was also found to be of 4.5% lower in the second period. Finally, HFI exhibited remarkable differences in some of the studied ponds between the two periods. Two factors were found to have a major influence on the reduction of the flooded surface of the ponds: altitude and distance to pumping facilities. The size and the maximum depth of the pond were also relevant to soften the disturbances in the natural hydrological regime.

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Session Classification : Poster with refreshments

Track Classification : Topic 6 - Groundwater, wetlands and natural heritage
Geometry and hydrogeological functioning of Ouled Bousbaa aquifer systems: Central Morocco

Monday, 23 September 2019 15:45 (15)

The study area is part of the Western High Atlas. The plain of Ouled Bou Sbaâ is located hundred kilometers west of Marrakesh, it is part of the Atlantic trays area. It is a complex basin, with a succession of synclines and anticlines oriented NE-SW between the mountain chain of the High Atlas and the Tensift river. The compilation of geological data, drilling data, geological sections and the analysis of the reconnaissance boreholes logs show that this area is constituted by thick sedimentary series dated from Paleozoic to Quaternary. Hydrogeologically, these series show the superposition of two aquifers; the first one is an unconfined groundwater flow system housed in the Quaternary, Eocene and Turonian; the second one is a deep confined groundwater flow system located at the heart of the Cenomanian-Turonian aged synclines. The feeding of these two reservoirs is ensured by the infiltration of surface waters of the high Atlas’s mountains as well as by stoma at the piedmont. By establishing piezometric maps, it has been noticed that on one hand the free groundwater layers have a hydraulic continuity. On the other hand the confined aquifer located at the Sidi Mokhtar’s syncline, in the north of the working area has a flow oriented from SSW towards NNE while the one in the syncline of Idouirane situated in the south has a groundwater flow oriented from SW to NE. As there is a separation materialized by the Marmouta anticline, the two aquifers do not have hydraulic continuity.

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Session Classification: Parallel
Track Classification: Topic 1 - Groundwater assessment and management
Groundwater impacts of underground infrastructure in London

Tuesday, 24 September 2019 15:00 (15)

Upgrades and improvements are essential to enhance the infrastructure of London, a city of over 8 million people. The London Infrastructure plan 2050 aims to improve the quality of life while London grows by creating ‘a greener and more productive city that is environmentally, financially, socially and economically sustainable and remains at the forefront of new technology.’ Much of the infrastructure in this dense urban area is underground, with developments becoming deeper and thus interacting with the groundwater in some parts of the city. Deep construction since 1990 includes a new railway, extensions to the London underground, water, road and cable tunnels. The deepest project is the Thames Tideway Tunnel, running for 25km along the River Thames to intercept overflows from the combined sewerage system, thus stopping discharge of raw sewage into the river when it rains. When fully operational in 2023, the tunnel will normally be partially full, surcharged only a few times a year, for a period of 1-2 days. The Lee tunnel at the eastern end opened in 2016.

The tunnel follows the axis of the plunging syncline across the centre of the London Basin. In general, there are two aquifers: a shallow superficial aquifer and the lower aquifer comprising the sandy Thanet Formation and the Cretaceous Chalk. The two aquifers are hydraulically separated by the aquitard of the London Clay and Lambeth Group. As the tunnel depth increases from 30m in the west to 80m in the east, it passes from low permeability strata into the principal Chalk aquifer. In east London, this presents a potential risk to groundwater quality, but also has provides an opportunity for improved understanding of the aquifer system through investigation and long-term monitoring of water levels and quality.

Over a 10-year period, the project team undertook an extensive investigation programme along the route and at the 22 shaft sites, geological characterisation, permeability and pumping tests, groundwater level monitoring and water quality testing in the Chalk and overlying strata. The extensive dataset collected has informed the design, engineering, groundwater risk assessments, and evaluation and mitigation of the impacts of construction and operation.

Pre-construction groundwater data was used to establish baseline conditions for both water levels and quality. Comprehensive risk assessment was required to satisfy the environmental regulators that the mitigation measures ensure that the construction of the tunnel and shafts did not pose an unacceptable risk to groundwater.

For the operational phase, risks during surcharging events were assessed through a series of simplified fate and transport models.

Since the easternmost 7 km of tunnel was completed in 2015, the monitoring results from commissioning and operation provide a reality check on the modelling and have allowed refinement of the risk assessments.

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Session Classification: Parallel
Track Classification: Topic 10 - Urban groundwater
Towards a holistic approach in characterising the water cycle in the Campine area (NE Belgium) at various temporal and spatial scales

The Neogene aquifer in the Campine area, northeastern Belgium, is a major water resource with many functions. It provides drinking water for the population, irrigation water for agriculture and water for industrial activities and recreational purposes. In addition, owing to its phreatic nature and the shallow groundwater table, it is a water supply for rivers and wetlands as baseflow. The quality and quantity of groundwater, and the geometry of the groundwater body is not only influenced by environmental changes, but also by specific human activities such as groundwater exploitation, polluting industries, deep and shallow geothermal energy, sand extraction etc. It is clear that a proper impact assessment of these activities and changes necessitates the development of well-calibrated and tested coupled hydro(geo)logical models.

Here we present the first steps taken into developing an innovative modelling framework to tackle the issue of changes in water cycle under future environmental change in small river catchments draining the Neogene aquifer. The framework includes (i) an integration of different components of the hydrological cycle into a coupled model focusing on unsaturated zone-groundwater-river water interactions at the catchment scale, and, (ii) the use of alternative state variables other than groundwater head, such as hydrochemical and age tracers, temperature, and palaeohydrological proxies.

In this presentation we will highlight various measurement techniques that we (plan to) use to quantify the water cycle in this particular setting. Results include: (i) groundwater exfiltration patterns in small creeks from infrared thermometry and 222Rn concentrations (smallest spatial and temporal scale), (ii) deep (a few decameter) temperature profiles from piezometers in discharge and recharge zones, (iii) CFC, 14C and 3H/He-based hydrochronological ages for an individual aquifer covering the last couple of decades and (iv) a catchment wide assessment of long-term hydrological variability deduced from historical maps and soil profile information covering the last few millenia. Combining these physico-chemical state variables obtained from various temporal and spatial scales will allow to calibrate and verify (coupled) hydro(geo)logical models in the most rigorous way.

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Session Classification : Parallel

Track Classification : Topic 5 - Tools, methods and models to study groundwater
Groundwater assessment in sand rivers in adaptation to climate variability and water scarcity: opportunities and challenges in semi-arid Africa

Warm semi-arid regions, covering vast areas of the African continent, are frequently considered of low potential for agricultural development, due to a limited and highly irregular access to water. Notwithstanding, significant amounts of freshwater can be stored in thick sand beds of wide ephemeral rivers, formed as a consequence of pronounced dryland weathering and erosion. Additionally, the storage capacity of these so-called sand rivers can be enhanced through sand dams. Here we present the combined results from three studies on sand river storage potential, recharge, hydrodynamics and water quality, in Tigray Ethiopia, Shashane Zimbabwe and Limpopo Mozambique. Results were obtained through a combination of remote sensing, fieldwork, data analysis and numerical modelling. Fieldwork involved: i) data collection on climate, river discharge and groundwater levels; ii) drone surveying of sand river geometry and groundwater levels in large diameter wells; iii) field testing on aquifer hydraulic parameters; iv) geo-electrical surveying; v) manual borehole drilling and vi) sampling for hydrochemical and isotope analysis. Data obtained from the field and laboratory were used to improve the conceptual understanding of these sand river systems and subsequently build numerical models to simulate their behaviour under natural conditions and possible scenarios of sand river abstraction. All areas show very rapid recharge at moments of surface runoff, revealed by piezometry, major ion chemistry and stable isotope signatures. Recharge is so quick that it is believed to delay runoff significantly in its early stages. Hydraulic connection between the sand river and its banks appears generally limited, except where paleochannels are in connection with the main sand river. Drone imagery in combination with drilling did reveal influent and effluent reaches of the sand river in Tigray (Ethiopia), of a much smaller magnitude (20-30 m wide and 2-4 m thick) than those in the other two areas (200-500 m wide and 5-10 m thick). High water salinity forms a major challenge in Tigray, as the large hydraulic gradient within the sand river promotes continuous groundwater outflow at the two constructed sand dam sites, also revealed by isotope analysis. Pumping groundwater directly from the sand river, rather than using shallow wells dug in the river banks, could mitigate the salinization problem. Numerical models show that flow within the system is in the order of meters per day, that available storage is naturally depleted by evaporation, and that sand river abstraction results in lower evaporation losses, with the potential to irrigate up to several ha per km in the largest sand rivers. Seasonal depletion of storage will be rapidly restored upon river flow in the following wet season, but will also lead to a partial reduction in runoff, possibly affecting users downstream, including dependent ecosystems, which is a topic of further study.

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Session Classification : Parallel
Track Classification: Topic 1 - Groundwater assessment and management
The environmental impact assessment of intensive groundwater abstraction on the groundwater flow and salinity of the Nadhour Saouaf Sisseb El Alem Aquifer System (Central Tunisia)

Monday, 23 September 2019 16:00 (60)

ABSTRACT
The Nadhour Saouaf Sisseb El Alem (NSSA) multilayer aquifer system is one of the most intensively used water sources in central Tunisia. Since the 1970’s, the growth in economic productivity linked to intensive agriculture in this semi-arid region has been sustained by increasing groundwater abstraction. The use of this aquifer system has augmented rapidly, ultimately causing depletion and salinization; to better understand its behavior and, to predict the groundwater flow and chemical evolution, the finite difference Groundwater Modeling System (GMS) software was applied. Groundwater levels observed in 1970 were used for steady-state calibration; levels from 1971 to 2015 served to calibrate the transient state. The impact of abstraction on the evolution of groundwater flow and salinity was studied through three hypothetical scenarios. The increase in abstraction rate of 30% and 50% in the first and second scenarios examine the tolerable extraction threshold. The results of increase in abstraction show a drawdown in the hydraulic head elevation of ≈17 m and ≈23 m; salinity was increased in 2.71 g/l. The center of the NSSA aquifer system is mostly affected. Abstraction was stopped in a third scenario, resulting in increasing groundwater reserves by ≈7 Mm³/year and a salinity response of 1.47 g/l. NSSA groundwater quality and reserves could be improved considerably if government abstraction rules were given serious consideration by the users.

KEYWORDS: Groundwater Abstraction, Depletion, Salinization, Groundwater Modeling System, hypothetical scenarios, Semi-arid Region.

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Session Classification : Poster with refreshments

Track Classification : Topic 1 - Groundwater assessment and management
Developing a process-based conceptual model for quantifying groundwater recharge in an upland sedimentary bedrock aquifer in a semi-arid region

Thursday, 26 September 2019 15:30 (15)

Estimation of groundwater recharge is a critical component of the hydrogeological characterization of contaminated sites, because recharge governs the rate of groundwater available to transport contaminants and its spatial variability influences flow path trajectories. To properly constrain recharge rates and to understand its spatially and temporal variability, application of multiple, complementary data sets using different techniques is needed. This is particularly true in semi-arid areas where fluxes are small and highly variable in space and time.

In this study, we present the results of a multidisciplinary approach that led to the development of a conceptual model of groundwater recharge in a sedimentary bedrock aquifer, located on an upland ridge in southern California. The area is semi-arid with potential evapotranspiration (1400 mm y⁻¹) exceeding the average annual precipitation (450 mm). Information about the spatial and temporal variability of recharge are required to inform the upper boundary of a 3-D groundwater flow model and to simulate plume fluxes.

Initially, a long-term site-wide (11.5 km²) recharge value was obtained by the application of the chloride mass balance based on measurement of bulk atmospheric chloride deposition, groundwater samples from 206 wells, and measurements of chloride in surface runoff during rain events. Secondly, the analysis of high-resolution porewater chloride concentration profiles from the vadose and groundwater zones at 11 locations, provided borehole-scale, long-term recharge values and indications about the portion of recharge through the matrix versus fractures in the vadose zone and the effect of land use changes on recharge. Finally, a high-resolution, spatially-distributed hydrologic numerical model (MIKE SHE) representing surface water and groundwater was used to simulate responses to precipitation from 1995 to 2014.

We found that the average annual site-wide recharge is 19 mm. However, simulated recharge values across the study area span over three orders of magnitude, from 0 to >1000 mm y⁻¹, as a function of topography, surface geology, and land use. This recharge occurs mainly at the end of the wet season and, occasionally, after exceptionally high-intensity precipitation events. Upon reaching the deeper vadose zone, on average, 80% of the flow towards the water table occurs as slow (decadal to century) intergranular flow in the rock matrix and 20% as faster fracture flow.

The use of different types of techniques (geochemical, modeling and physical methods), at the proper resolution, was fundamental to uncover the hydrologic processes in the unsaturated zone, to investigate the influence of the surface and subsurface factors on recharge and, thus, to assign rules for recharge across the entire site in the flow model. This is particularly important because this quantitative conceptual model helps to understand recharge conditions and contaminant fluxes from source areas that affect the rate of contaminant migration and attenuation in groundwater.

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Session Classification : Parallel

Track Classification : Topic 5 - Tools, methods and models to study groundwater
A quantitative appraisal of groundwater head time-series measurement: How well are we doing?

Monday, 23 September 2019 17:00 (15)

Accurate determination of subsurface water levels is essential for the reliable quantification of hydraulic head gradients from which groundwater flow is inferred. Head measurements also underpin the quantification of hydrogeological properties based on aquifer pumping tests or tidal propagation analysis. While measuring a water level seems an easy task, the collection of water level time-series data is by no means trivial and there is a high potential for errors and misinterpretation. In this contribution we comprehensively analyse the individual measurements required to determine hydraulic heads and gradients: (1) geo-spatial positioning, (2) manual water depth, (3) automated pressure, and (4) spatial reference point for the head. For each component we determine the systematic and random errors based on our own data sets and field experience, as well as data from the literature. We assessed the effects of instrument and clock drift, variable density inside the piezometer, borehole inclination, well aging and instrument performance. By propagating the minimum achievable random measurement errors for horizontal and vertical hydraulic gradient calculations we evaluated the accuracy with which groundwater flow processes can be quantified using current best practice. The largest errors contributing to hydraulic head and gradient uncertainty originate from borehole inclination and manual water depth measurement, respectively. Our analysis demonstrates that resolving head gradients, which are smaller than 0.01 for boreholes that are closer than 10 m, requires extraordinary effort.

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Session Classification : Parallel

Track Classification : Topic 5.3 - Advanced modelling tools for subsurface hydrology: from the vadose zone to deep environments
Insight the Western Andean Front Hydrogeology using springs geochemistry: the case of Aconcagua Basin (Central Chile)

Thursday, 26 September 2019 17:45 (15)

In arid and semiarid regions, a significant component of recharge to sedimentary basin aquifers occurs along mountain front zones (i.e. mountain front recharge and mountain blocks recharge). **Central Chile** is characterized by a north-south Central Depression (~400 m a.s.l) filled by Quaternary alluvial deposits and bordered to the east by fractured volcano-sedimentary rocks of the Andes (2000-4000 m a.s.l). At 33°S, mean annual precipitation varies with the orographic gradient from 200 mm yr⁻¹ in Central Depression to 550 mm yr⁻¹ in the Andes. Considering the geomorphological and hydroclimate features, the Western Andean Front is a high interesting area for the recharge of adjacent sedimentary basin aquifers.

However, in Chile, mountain front zones are often considered as impermeable boundaries and not used in aquifer modelling. Thus, generally the main aquifer recharge is associated to river infiltration. We suggest that this simplification do not provide a properly assessment of Central Chile groundwater resources. This has a great relevance in water budget, especially considering the prolonged drought with severe withdrawals in rivers and dams occurring since 2010. Because water is a strategic challenge for socio-economical activities, the assessment of groundwater recharge contribution from the Western Andean Front is mandatory for improve the understanding of aquifers functioning and to national groundwater management plans.

Using hydrogeochemical approach in the **Aconcagua basin** (32°50'S), where several springs outflowing at different elevations, we provide the evidences of groundwater recharge within the Andes. Water from springs, boreholes and precipitation were sampled for major, minor, trace elements and stable isotopes (δD-δ18O) analyses. Electrical conductivity (EC), temperature and pH were measured in situ.

Preliminary results show that EC ranges between 14 to 1188 µS/cm, temperatures are between 11.5 to 27°C and pH vary from 5.7 to 8.5. Waters are mostly HCO₃⁻Ca⁺² types. Most of major ions have a negative correlation with the altitude, unlike the temperature and pH. Furthermore, Ca⁺² vs HCO₃- plot indicates that the main process which controls the chemistry along a same groundwater flow path is the anorthite weathering in presence of CO₂. By other hand, stables isotopes indicate that evaporation is affecting the spring’s waters while not the borehole’s waters. Spring geochemistry provides information about hydrogeological processes in the Western Andean Front. The increase of ions concentrations from the highest springs in the mountains to the boreholes water in the basin, and the same process controlling the chemistry, suggest that the Andes are connected with the basin. Therefore, first results indicate that the **Andes in Central Chile have an important role in the recharge of Central Depression sedimentary aquifers**.

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Session Classification : Parallel

Track Classification : Topic 9 - Groundwater and socio-economic development in Latin-America
Comparative Analysis of impacts of groundwater droughts in a European context

Monday, 23 September 2019 16:00 (60)

Groundwater is of crucial importance for society, as it can uphold provision of hydrological services when there is a lack of water during drought. However, when droughts extend over longer periods of time and groundwater abstraction is increased, longer-lasting groundwater droughts can develop, aggravating existing water shortages and impacting groundwater-dependent environmental systems. This complex interaction means that groundwater contributes to mitigate droughts, but may also during longer droughts exacerbate drought hazards impacting society. In theory, it is understood that this interaction exists. However, to date no study used empirical data on how and when groundwater is factually reported as a mitigation agent or as an impact agent. In this study, we build on previous efforts to synthesize text-based reports on drought impacts in the European Drought Impact Inventory (EDII). We extended the EDII with additional, groundwater-related reports. We then analysed the EDII data to find out: a) how is society impacted by groundwater drought?, b) how is groundwater used during drought?, c) is the role of groundwater during drought different in different climatic or legislative settings?, and d) did the role of groundwater during drought change over time? To answer these questions, we isolated the EDII reports that directly relate to groundwater, and mapped them onto new groundwater-related impact categories. We qualitatively summarized the way groundwater is reported as an impact, or as a mitigation agent, and provide statistics on the frequency of each occurrence. We further present the temporal development of the reporting, and compare the type and number of occurrence of groundwater-related reports between the UK, the Iberian Peninsula (Spain and Portugal) and the DACH region (Germany, Austria, Switzerland). The study provides the first systematic documentation of groundwater impacts and use during drought. It will thus provide guidance for researchers and water resource professionals considering whether groundwater can be used sustainably as an alternative resource during drought under different circumstances.

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Session Classification : Poster with refreshments

Track Classification : Topic 1 - Groundwater assessment and management
Groundwater dependence in the Southeastern region of Brazil has increased during the last 30 years, especially to supply the rising agricultural production and multiple water uses in its growing cities. Knowledge about aquifer recharge is crucial for preventive water resource management, especially under climate change scenarios. Encompassed within the hydrogeological framework of the Parana Sedimentary Basin the Bauru Aquifer System (BAS) and the Guarani Aquifer System (GAS) are responsible for supplying water to more than 10 million inhabitants in the state of São Paulo, and recharge conditions in these aquifers have been poorly studied, despite the importance of groundwater for the state. Isotopologues of water represent a completely conservative tracer of water movement through the hydrological cycle, making possible determine the relation between climatological features and groundwater recharge. Since 2013 groundwater samples from two shallow wells (30 meters depth) and precipitation samples have been collected in two sites located in the recharge area of BAS and GAS aiming to evaluate variations in isotopic composition, and how the isotopic signal of precipitation could be transferred to groundwater through recharge. Seasonal variations in groundwater levels were modulated by local precipitation regimes, and large climatological features, such as the 2014-2016 ENSO event, which was responsible for a continuous lowering of water levels observed until 2016. Isotopic composition of precipitation in both sites presented large variation (variation on d18O up to 16‰) and were marked by strong seasonality with enriched values observed during dry season while depleted values during wet season. During most part of the year d-excess values were higher than 10‰, indicating the influence of moisture recirculation processes during air masses displacement. The calculated weighted average values for d18O in precipitation were -5.70 and -5.10‰, respectively for BAS and GAS sites. Groundwater isotopic composition presented small variations when compared to precipitation (variation on d18O less than 1.5‰). Despite small isotopic variations in groundwater, d-excess values presented large variation, and most samples positioned below the local meteoric water line, indicating the occurrence of strong evaporative processes associated to kinetic fractionation along the unsaturated zone. Average values for d18O in groundwater were -6.93 and -7.25‰, respectively for BAS and GAS sites, which were more depleted than weighted average precipitation. However, such values are similar to isotopic composition of precipitation during the wet season, when the South America Monsoon System is very active, and a large amount of vapor recycled from the Amazonian region is available in the atmosphere and is responsible for the formation of the South Atlantic Convergence Zone. These findings could shed light on past climatic conditions associated to recharge of very old groundwater (up to 500 ky) found in confined portion of GAS.

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Session Classification : Parallel

Track Classification : Topic 2 - Groundwater and climate change
Fault zones exert strong controls on the hydraulic properties and groundwater circulation. Uncertainties about the complex geometry and boundary conditions of hydrogeological systems in mountain front zones difficult the groundwater resource exploration. As a result, Chile has focused the studies and exploitation of aquifers to alluvial-plains considering exclusively aquifer-river relations and neglecting any contribution from the western front of the Andes. The increasing water demand for agriculture together with a mega-drought have depleted the alluvial-plain aquifers of Central Chile. In this context, our effort is to improve the knowledge about groundwater resources of the andean mountain front and the role that can play for the water resources of the region.

This study addresses the geometry and the boundary conditions of the semi-arid western front of the Andes, taking as a case-study the Pocuro Fault Zone (PFZ) at 32°50’S. PFZ is a north-south striking piedmont fault zone, which extends 150 km long and 2 km wide. In the landscape, PFZ puts the Andes range (~ 3000-4000 m a.s.l) and the Oligo-Miocene volcano-sedimentary sequences in contact with the quaternary alluvial deposits of the Aconcagua Basin to the west (~ 800 m a.s.l). We measured 460 gravity points spaced ~ 100 m apart (with CG-5 equipment), and eight electrical resistivity tomography (with Terrameter LS2 equipment), cumulating ~10 km length. The gravity data was processed follow the standard procedure and the electrical inversions were completed with ZonRes2D. Results were compared with springs locations, water table depth in observation boreholes, groundwater electrical conductivity measurements, and geomorphological-geological surveys.

Preliminary results show significant gravity anomaly variations along profiles: with (i) a null anomaly up the hill due to fresh and damaged rocks and (ii) an asymmetric negative anomaly to the west of the fault trace due to around 100 m thick depocenter of non-consolidated alluvial deposits in the basin. Electrical resistivity measurements and groundwater features (water table depth, electrical conductivity and spring locations) allow us to define three possible hydrogeological domains: fractured/damaged rock, fresh rock and sediments. Furthermore, lowest resistivity values in a subvertical band, corroborated with geological surveys, allow a mapping of faults in depth.

Finally, the use of two complementary geophysical methods, geological mapping and hydrogeological data, provides a more robust understanding of groundwater resources along the western front of the Andes.

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Assessing hydrogeological system ...

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**Session Classification:** Poster with refreshments

**Track Classification:** Topic 9 - Groundwater and socio-economic development in Latin-America
Development and Application of Approaches for Geosphere Modelling in Support of Adaptive Phased Management: An Overview

The Nuclear Waste Management Organization (NWMO) was established in 2002 by Canada’s nuclear electricity producers in accordance with the Nuclear Fuel Waste Act (NFWA). The NWMO is responsible for implementing Adaptive Phased Management (APM), Canada’s plan for the long-term management of used nuclear fuel. The technical end point of APM is the centralized containment and isolation of the used fuel in a deep geological repository (DGR) located in a stable crystalline shield or sedimentary bedrock formation. The DGR concept comprises multiple barriers to contain and isolate the used nuclear fuel for time frames of 1 Ma. A key component in the DGR concept is the surrounding geosphere, which acts to protect the engineered barrier systems, to preserve a stable environment in which radionuclide migration is minimized, and to create a barrier to inadvertent intrusion. At a depth of approximately 500 m, the ability of the geosphere to act as a natural barrier is governed by site-specific features and attributes.

The NWMO is pursuing an active geoscience program into the long-term evolution of crystalline and sedimentary geospheres, which includes collaboration with Canadian and international experts, focused on a wide range of topics related to the development of DGRs for the safe containment of used fuel. The primary objectives in developing geosphere models are to: 1) support site selection and future site characterization activities; 2) advance the understanding of the geosphere in terms of stability, predictability, and resilience to long-term perturbations; 3) substantiate the role of geoscience in establishing support for a DGR safety case; and 4) maintain a high level of competency and a credible Canadian-based technical program. This is achieved through the development of approaches for evaluating and interpreting geosphere properties, groundwater system behaviour and predictions of long-term geosphere and DGR performance. The evolution of deep-seated groundwater systems in fractured crystalline rock is illustrated in part through the integrated application of fracture network, groundwater, and glacial system modelling.

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Session Classification : Poster with refreshments

Track Classification : Topic 1 - Groundwater assessment and management
Regional Groundwater Contamination Related to Exploration & Production of Natural Gas – Pavillion Gas Field, Wind River Basin, Wyoming USA

Tuesday, 24 September 2019 12:00 (15)

The Pavillion gas field is located in the Wind River Basin in north central WY, USA. Since the 1960s natural gas has been produced from the Tertiary age Wind River Formation which is comprised of lithologies associated with a fluvial depositional system. Commercial and non-commercial gas deposits, which originate in the underlying Ft. Union Formation, occur in discontinuous permeable sandstone and siltstone traps within the Wind River Formation which is about 1077 meters in the Pavillion area. Uncommonly shallow non-commercial deposits occur at depths less than 300 meters below the ground surface. There is no confining unit separating deeper, commercial gas zones from shallower, fresh water zones. Production in the gas field has occurred using conventional vertical wells and hydraulic fracturing, which was utilized at depths as shallow as 275 meters. About 170 vertical gas production wells have been completed within the 65 km2 gas field. In the early 1990s production well spacing increased from 1 well per 259 hectares to one per well 16.2 hectares. It is estimated that more than ½ of 170 wells were constructed and / or abandoned using methods and practices that are not appropriate for the hydrogeologic setting. There are 57 unlined pits which were used for disposal of drilling fluids and mud. Diesel based drilling fluid was used until the early 1990s. The upper part of the Wind River Formation functions as an aquifer and is the source of domestic and drinking water for numerous ranches and public water supply for the town of Pavillion. Approximately 90-100 water wells produce from the Wind River aquifer within the Pavillion gas field with depths range from 15 to 265 meters. In the early 1990s residents began experiencing taste and odor problems with domestic water. In 2005 a "blowout" fire occurred while drilling a new domestic water well. Groundwater quality data from 37 domestic wells, public water supply wells and two deep monitoring wells, obtained during the past 10 years, indicates significant groundwater contamination has occurs throughout a large area within the gas field. Contaminants include petroleum hydrocarbons (BTEX, DROs, GROs, methane), VOCs and SVOCs, metals and methanogenic and sulfide reducing bacteria. The primary sources of these contaminants are infiltration and migration of fluids from unlined pits, migration of drilling / production fluids and stray gas migration from improperly constructed /abandoned production wells. At least 10 domestic wells are located less than 300 meters from an unlined pit or a producing gas well. The United States Environmental Protection Agency, the Wyoming Department of Environmental Quality and local NGOs have been engaged in assessing the nature and extent of contamination and evaluating potential remedies that will provide sustainable water supplies to the effected water well owners.

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Session Classification : Parallel

Track Classification : Topic 8 - Groundwater quality and pollution processes
Douala city, located in the littoral province of Cameroon, receives abundant rainfall quantities due to its geographical position in the gulf of Guinea and bears considerable surface water and groundwater resources. Due to socio-economic development and rapid demographic growth and its consequences of unplanned urbanization and improper sanitation system, these water resources are poorly protected and managed. Streams occurring the Wouri watersheds are mostly used as waste water discharge and hundreds boreholes have been drilled to the aquifer system without any management plan. A detailed geological, hydrodynamic and hydrogeochemistry study in Douala town and vicinity was conducted to get a better insight of the groundwater system functioning. Three field campaigns were carried out with 225 samples collected and analyzed for major ions and silica, stable isotopes ($\delta^{18}$O, $\delta^{2}$H, $\delta^{13}$C), tritium (3H) and 14C.

The system have been reconfigured through petroleum and hydraulic lithologic boreholes data for a thickness of 200 m and two main geological and hydrogeological formations have been defined such as the superficial system namely Mio-Pliocene/Quaternary aquifer (0 to 70 m of depth) and the intermediate system namely Upper Eocene/Oligocene aquifer (70 to 200 m of depth). The general hydrochemistry is characterized by the chloride water type as the dominant one, mixed water type are also represented and to a lesser extend bicarbonate water type. The Q-mode HCA for both of systems decipher 4 main clusters C1 to C4 according to the major ions and silica and the hydrogeological conditions. Then, the R-mode FA stand out the mineralization processes. These latters coupled to the isotopical results confirm the general hydrodynamic schema where modern groundwater types indicate silicate minerals weathering as the main geochemical process, allitization and monosiallitization as the principal pedogenetical processes and calcite dissolution (C1 and C2). Whereas sub modern groundwater type mostly show silica deposition, ion exchange and to a lesser extend other carbonate minerals dissolution (C3 and C4) and bisiallitization as the main pedogenetical process occuring. Furthermore, the spatial distribution of stable isotopes exhibit a groundwater enrichment gradient from the recharge areas (NE) to the main catchment (Wouri River). Depleted isotopic contents of superficial aquifers are closed to rainfall signature contents, attesting of direct infiltration. Mixing water characterize vertical flow acting in both systems precisely in the lower part/semi-confined aquifer of the Mio-Pliocene/Quaternary and in the upper part/semi-confined aquifer of the Upper Eocene/Oligocene. Radiocarbon reveal ages from few hundreds to thousands for the Upper Eocene/Oligocene aquifer system. These results refine understanding of the aquifer system functioning which is essential to provide a reasonable basis for effective groundwater control measures and sustainable water management in the study area and the entire sedimentary basin of Douala.

**Key words :** hydrogeochemistry, groundwater resources, management, Douala basin, Cameroon

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**Session Classification:** Poster with refreshments

**Track Classification:** Topic 1 - Groundwater assessment and management
Utilising hydrocarbon exploration data for the search to deep groundwater.

Tuesday, 24 September 2019 16:00 (60)

The most important source of water in rural Africa is groundwater, which is traditionally extracted from shallow aquifers, drawn or pumped from wells in weathered basement. To be able to explore groundwater in deeper targets different methods need to be utilised. In the late 1970’s and early 1980’s, the Kimbiji peninsula in Tanzania was subject to extensive hydrocarbon exploration. Seismic profiles were shot and exploration wells were drilled. No oil was discovered at that time, and the information was shelved. 40 years later this data made it possible to discover structures that were drilled for water.

Ruden Geo Solutions decided in 2005 to take a closer look into the deeper subsurface. They combined applied hydrogeology and data from the hydrocarbon industry resulting in the discovery of the Kimbiji aquifer, which is presently serving more than 2 million people with fresh water. This discovery was done entirely based upon information from hydrocarbon exploration conducted in the area.

Following the discovery of the Kimbiji aquifer, at the Kimbiji peninsula in Tanzania, a project was undertaken by the Government of Tanzania to verify the potential existence of a regional coastal aquifer system. In the late 1970’s and early 1980’s, the Kimbiji peninsula was the subject of extensive hydrocarbon exploration. More than 1100 km 2D seismic profiles, that were reprocessed to a depth of 2000 meter, and information from 6 exploration wells was used to improve the definition of the Kimbiji aquifer system.

Based on the discovery in Tanzania, Ruden Geo Solutions developed a search model for finding deep groundwater entirely based on this innovative combination of hydrocarbon exploration data in a groundwater context.

The use of hydrocarbon exploration data allows the hydrogeologist to look much deeper than is conventionally possible with standard approaches and methods of hydrogeology, mainly because the water sector alone does not have the resources to investigate at similar scales or depths. The top few hundred meters of the subsurface environment is generally of limited interest to the hydrocarbon exploration programs, and hence, although shallow seismic data are normally acquired, they are not necessarily processed. In contrast, this upper/shallow section represents the target zone for deeper groundwater exploration. However, with no economic incentives, or because of confidentiality issues, the hydrocarbon industry will not volunteer to share this valuable information.

These are challenges that need to be overcome to make the search for new and deeper groundwater resources possible. How can it be made attractive for oil companies to share their data? And what can the water sector possibly mean for the oil industry in return?

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Session Classification : Poster with refreshments
Track Classification: Topic 5.4 - Innovative approaches for understanding groundwater flow systems
Understanding and evaluation of water resources is important for sustainable use of water in the future. Due to increasing needs of water resources and changes of climatic conditions, an increasing problem of the water scarcity occurs. For efficient water management planning the knowledge of both, natural characteristics of water sources (geological and structural conditions, climatic characteristics) as well as the impact of human activities on wider area, which can have a significant impact on the quantity and quality of groundwater, is crucial.

A great part of Slovenia characterises carbonate rocks (limestone and dolomite) in which karstic and fractured aquifers occur. Because of their complexity and often inaccessibility, several karstic terrains still have a great potential both for exploration and also exploitation. Such systems are potential reservoirs of high quality water and can be important sources of drinking water in the future. Because these systems are complex, the right methodological approaches are crucial in all stages of investigation; planning, investigating, evaluating and finally use.

The study presents the results of the comprehensive approach of the case study of Učja Valley aquifer. Planned and actually used methods were selected with the aim to understand the water flow and to design the conceptual model of the aquifer. The results showed that the systematic research and combination of methods are essential. Fundamental research presents the geological understanding of the area (geological mapping), which gave the important base and information for further planning of analyses (hydrogeochemistry, trace experiments etc.), and are also crucial for final interpretation. The investigation reveal that proper methodological approach can help to avoid unnecessary additional analyses which would not in themselves provide sufficient data for interpretation or even useless value.

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Session Classification : Parallel

Track Classification : Topic 7 - Karst Hydrogeology
Understanding the potential of Nature Based Solutions to recover the natural ecosystem services of the Medina del Campo Groundwater Body in the NAIAD EU project

Monday, 23 September 2019 17:30 (15)

The area covered by the Medina del Campo Groundwater Body (Duero River Basin, Spain) is an important agricultural production region. The area is prone to climatic and geomorphological hazards such as floods, dry spells and landslides. Climate projections indicate that these hazards might become more frequent in the future. The main economic activity of the area is agriculture, which is also the main water user almost entirely relying on groundwater. Currently there are more than 5000 wells pumping groundwater to supply the agricultural water demand. Measurements show that groundwater levels have declined up to 20 m in some areas in the last 40 years. In the framework of the NAIAD H2020 project we developed a 3D numerical groundwater flow model with the objective to understand the dynamics of the groundwater, to evaluate the impact of climate change, and to assess the potential of some Nature Based Solutions (NBS) for recovering the original ecosystem services of the groundwater body. The model was built to simulate a pristine system without abstractions, and a system under anthropic pressure with the current abstractions. The NBS simulated include the artificial recharge of the aquifer, the change of crops, and the modification of abstraction rates and distribution. The preliminary results indicate that under a scenario of climate change with reduced precipitation, although the assessed NBS solutions can be beneficial, they are not able to totally reverse the impact caused by the abstractions, and therefore do not succeed to completely restore the original ecosystem services of the groundwater body.

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Session Classification : Parallel

Track Classification : Topic 1 - Groundwater assessment and management
Major issues in groundwater and surface water quality in Cambodia and Myanmar

Tuesday, 24 September 2019 15:00 (15)

Major cities in Cambodia and Myanmar are experiencing rapid growth and development with little regard to groundwater and surface water quality. Studies have been done in Southeast Asia to determine some of the major issues facing the cities with a focus on lack of treated wastewater disposal. In Phnom Penh, Cambodia Boeng Cheung Ek wetland is a large, peri-urban, free water surface, wastewater treatment wetland that services approximately 90% of combined storm water and untreated municipal wastewater from the city. While there are plans to fill in nearly the entire wetland, the construction of a wastewater treatment plant has yet to begin. We hope this research will help inform the sustainable management of wastewater in the city. The objective of this study is to characterize the spatiotemporal variability of contaminants in wetland surface water and determine whether infiltration to groundwater has occurred. The wetlands have been shown to do provide some reduction in water quality parameters but are still contaminating local wells. In Mandalay, Myanmar textile dying and weaving of traditional longyi garments has occurred in the Amarapura Township since 1822, transitioning from natural to chemical dyes in the early 1900’s. With no current wastewater treatment facilities in Mandalay, dye effluent mixes with other wastewaters in unlined canals dug near peoples’ homes and discharge into local rivers and wetlands. As locals rely heavily on dug and tube wells next to the wastewater canals for their drinking, bathing, and cooking, this industry poses a major health hazard to people in this region. The objective of this study is to identify and quantify the concentrations of major ions and heavy metals found in textile dyes effluent and determine the impact on local groundwater resources. Results identified heavy metals in varying concentrations throughout each step of the dyeing process. Textile dying along with wastewater from homes is a major source of pollution and a health hazard to the people within the Amarapura Township, however locals are not readily connecting the dye practices to the issues with their drinking water. Both of these studies highlight the importance wastewater on water quality in the areas and that development needs to be linked to improved wastewater treatment.

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Session Classification : Parallel

Track Classification : Topic 8 - Groundwater quality and pollution processes
Modeling continuous and extreme hydrological events in the Oued Laou catchment using ATHYS hydrological platform.

In this study the hydrological modeling platform (ATHYS) was used to model the rainfall-runoff relationship in the sub-humid Mediterranean basin, the Laou River (area: 940 km²) in northern Morocco. This watershed is characterized by strong storms associated with heaviest rainfall in Morocco. ATHYS platform has been tested in continuous time between 2004 and 2012 and in four hourly extremes events recorded in March 2018 at the Kodiat Korireen station. On the VI-CAIR model we visualize, analyze and correct spatialized geographical data in the raster form, on VISHYR we have performed the correction, calculation, management and visualization of local hydro-climatic data of the Laou catchment. Under the MERCEDES model the combination of the Soil Conservation Service (SCS) production function and the Lag and Route (L&R) transfer function has produced satisfactory results for continuous simulation periods and extreme scenarios. The modeling of the flow process in the Laou River by the ATHYS platform resulted a reasonable performance with an NSE of 0.63, R² of 0.65, PBIAS of 15% and RMSE of 0.59. Results indicate that soil storage parameters and soil type as well as land use and vegetation are the most important parameters impacting on the sensitivity of the hydrological response in Laou basin. Findings indicate that the ATHYS models are appropriate tools for modeling floods and volumes of flow associated with specific rain events and could be used by managers and decision makers as a predictive flood tool in Morocco and worldwide.

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Session Classification:  Poster with refreshments

Track Classification:  Topic 1 - Groundwater assessment and management
Groundwater/surface-water interactions and their effect on nitrate pollution in the Oglio River basin (Northern Italy)

Monday, 23 September 2019 18:00 (15)

In the Po Plain of northern Italy, one of the larger alluvial basin in Europe, groundwater quality is threatened by nitrate pollution. The main aim of this work is to assess the origin of this pollution and understand how groundwater/surface-water interactions affect nitrate concentrations in the region.

The study area is part of the Oglio River basin and covers around 1,900 km$^2$ between the outflow from Lake Iseo and the confluence with Mella River. The northern part of the area (i.e. higher plain) hosts a sandy mono-layer aquifer that passes southwards into a multi-layer aquifer (lower plain) with increasing silt and clay contents. The transition between higher and lower plain is marked by a series of semi-natural springs, the so called “springs belt”. The Oglio River is losing in its first ~30 km crossing the higher plain, then becomes gaining. The area is crossed by hundreds of irrigation channels fed by Oglio River water.

Six field surveys (November 2015, February, June, September 2016, March and July 2017) were carried out and up to 58 groundwaters, 20 Oglio River and tributaries waters, 7 spring waters and 1 Lake Iseo water were sampled in each survey. Analyses were performed for major ions, trace elements and stable isotopes ($\delta^{18}$O/$\delta^{2}$H in water, $\delta^{18}$O/$\delta^{15}$N in nitrates and $\delta^{11}$B).

Concentrations of NO$_3$ were higher in groundwater from the higher plain and spring water (median of 39.8 and 40.6 mg/L, respectively) than in groundwater from the lower plain, where NO$_3$ was generally below the detection limit. The losing reach of the Oglio River had low concentrations of NO$_3$ that nevertheless increased downstream from a median concentration of 2.5 mg/L at Lake Iseo to 20.6 mg/L in its lower gaining reaches. This is due to the gaining of groundwater from the higher plain that is higher in NO$_3$.

Isotope data showed that NO$_3$ originated from different anthropogenic sources, such as animal manure, septic tanks and, to a lesser extent, synthetic fertilizers. Beneath intensively-irrigated areas, the isotopic composition is shifted through the compositional range of synthetic fertilizers. This could be due to an increased dissolution of fertilizers related to the intensive irrigation. Irrigation also plays an important role in controlling groundwater NO$_3$; concentrations are lower (mean 38.4 mg/L) where irrigation water is sourced from the channels and higher (mean 56.4 mg/L) where irrigation is performed using groundwater. The difference arises because irrigation channels carry Oglio River water, that has low NO$_3$ concentrations (mean 8.5 mg/L). Therefore, in this case, irrigation water contributes to diluting the high anthropogenic NO$_3$ contents in groundwater. This finding is supported by water isotopes since the Oglio River is more depleted than local precipitation.

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**Session Classification:** Parallel

**Track Classification:** Topic 8 - Groundwater quality and pollution processes
Groundwater flow modelling: A decision-making tool for water resource management in coastal areas - Case study of the Oussouye plateau (South Senegal)

The Continental Terminal (CT) aquifer in Casamance (Southern Senegal) is one of the main sources of fresh water for usual activities. This shallow aquifer especially in the Oussouye plateau, bounded largely by salt brackish water (locally called bolongs) and the Casamance River is very vulnerable to intensive abstractions that could influence saline intrusion advance. The increase in water demand and the lack of boreholes there are leading the authorities to set up a rational management system for this aquifer. The aim of this study is to set up a management and decision-making tool through a groundwater modelling for an efficient and sustainable exploitation of this vulnerable aquifer.

The methodological approach particularly geophysical, hydrogeological and hydrochemical investigations aim to develop a conceptual model of the CT aquifer functioning. Two field campaigns were carried out (June and October 2017) to measure physicochemical parameters and groundwater sampling. All the sampling points were then surveyed by differential GPS to define the piezometric map and thus the groundwater flow. The geometry and hydrodynamic parameters (conductivity and transmissivity) of the CT were approached using geophysical technics (electrical methods) but also the drilling logs from previous studies carried out in Oussouye region. These investigations made it possible to define the conceptual model of the aquifer and to build the mathematical model under the Visual modflow interface with the Modflow-2000 code developed by USGS. This model takes into account the abstractions of current boreholes and dug wells where pumping rates were investigated by statistical survey.

The results show a general groundwater flow towards the bolongs and the Casamance River from two domes located in the Nord and in the center of the plateau which represent the recharge zones. Electrical conductivity varies from 28 to 1314 µs/cm with high variance and standard deviation values reflecting variable sources, geochemical and dilution processes occurring in the plateau. Despite physiochemical data, the analysis of water samples show an excellent groundwater quality. Major elements contents meet WHO standards except the Iron contents (Fe) which are relatively high in some wells due to the nature of the aquifer formation. The mathematical model was calibrated in steady state. The average difference between simulated and observed head is 0.08 m, while the average absolute difference is 0.24 m. Simulations under transient conditions showed that the groundwater is vulnerable to high pumping rate due to the drawdowns at the catchment wells, which can reach 7m for 75 m³/h. This significant drawdown should be avoided for this type of piezometric configuration where the maximum hydraulic head is 6m. However, the model revealed a sustainable groundwater potential for the needs of local and neighboring populations by transfer at 50m³/h with a steady state regime system reached after 10 years.

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Session Classification : Poster with refreshments

Track Classification : Topic 1 - Groundwater assessment and management
Atmospheric nitrogen originated in a highly human impacted area: from deposition to infiltration and drainage in the vadose zone

Tuesday, 24 September 2019 15:15 (15)

Nutrients that fall on the ground from the atmosphere represent a minor component of the total nitrogen input to soils, especially when compared to agricultural, civil and industrial inputs (i.e., sewage treatment plants or sewage systems, fertilizer and manure applications). However, integrating all nitrogen forms, processes and scales can represent a breakthrough challenge for the understanding and the management of the nitrogen cycle.

A monitoring experiment was set up to collect wet atmospheric depositions in a human impacted area with multiple land uses, representing different emission sources (i.e., extended urban areas with residential buildings and industrial activities, high traffic roads and agricultural activities). Wet deposition is measured at 17 sites, homogeneously distributed in the western sector of Lombardy Region (northern Italy), in the surroundings of Milan. Rainwater collection was executed almost at each single rainfall event at all the sites, starting from February 2017 to February 2019. In summary, 16 precipitation events were monitored and 155 rainwater samples were collected, involving, on average, 10 sites each time. After collection, samples were analysed for pH, electric conductivity, ammonium, nitrate, nitrite, major cations (calcium, magnesium, sodium, potassium), and major anions (sulphate, chloride, fluoride).

In June 2018, an instrumented field site has been settled to reconstruct the path of nitrogen from the atmospheric emissions to rainwater precipitations to soil and groundwater, monitoring the infiltration and drainage processes in the vadose zone. The field site is located within a well field of the public manager of the water service of the Province of Milan, 20 km east from the City of Milan.

Results show a direct relationship between high levels of air pollutants (e.g., nitrogen dioxide, sulphur dioxide, ammonia) and relatively high contaminant concentrations (e.g., nitrate, sulphate, ammonium) in rainwater samples. Consequently, given an average annual precipitation of about 800 mm for the period 2016-2018, a wet deposition of inorganic nitrogen equal to 9 kg(nitrate-N)/ha·yr and 15.5 kg(ammonium-N)/ha·yr was estimated. Considering both the variability of the spatial or temporal distributions of precipitations and the variability of concentrations of nitrogen compounds in rainwaters, the total amount of nitrogen depositions can range between 20 and 30 kg/ha·yr in the study area.

As leaching of nitrogen compounds from soils generally increases at nitrogen deposition rates higher than about 10 kg/ha·yr, this work suggests that the nitrogen atmospheric input to soils could not be neglected when evaluating the impacts of nitrogen sources to terrestrial and aquatic ecosystems, as well as to groundwater resources. This highlights the need of wisely integrating air, soil and water policies for the planning and the management of equitable and sustainable cities.

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Session Classification: Parallel

Track Classification: Topic 10 - Urban groundwater
Quantitative Analysis of Daily Discharge Records - Example of Big Spring, Missouri

Thursday, 26 September 2019 17:45 (15)

Big Spring, located in the Ozarks region (Carter County, Missouri), is one of the largest karstic springs in the United States and the world in terms of flow. With an average flow of 12 m³/s and an average daily discharge of 1.106 m³, this spring is a first magnitude spring which rises at the base of a dolomite cliff at the west side of the Current Valley, Ozarks.

The characterization of porous aquifers is based on knowledge of internal parameters such as permeability, transmissivity and geometry, and their boundary conditions. Unfortunately, the mechanisms of genesis and development of karstic systems (karstification) lead to a highly discontinuous and heterogeneous medium, not only in its spatial structure but also in its temporal functioning. Various degrees of karstified carbonate rocks consist of highly transmissive conduits through poorly transmissive blocks. Moreover, climate and tectonic movements change base level conditions, i.e. spring location, creating multilevel conduit karst systems.

We analyzed the daily discharge records collected by the USGS from 1921 through 1996 using the approach developed by Mangin (1975) and modified by Bakalowicz (2005). We characterized the infiltration (slow, fast or delayed) and estimated the dynamic volume, i.e. the phreatic storage easily renewable during yearly recharge. This approach is only based on the hydrogeological functioning of the karst aquifer. Four recession curves (1944, 1953, 1969 and 1972) were considered for Big Spring karstic system during long term summer recessions. The analysis of these curves indicated the presence of an unusual important dynamic volume varying between 570 106 m³ and 1.109 m³, a predominance of slow infiltration, and residence times varying between 1.5 to 2.5 years.

The analysis of the sorted discharge curves prepared for the analyzed period showed a systematic break at a discharge of 10 m³/s, indicating that Big Spring is in hydraulic contact with another aquifer (probably alluvial) and is discharging significantly into this adjacent aquifer, below this discharge value.

When compared to karstic springs around the world, it shows that Big Spring is characterized by a deep phreatic zone, largely karstified below the present day spring level, during previous karstification phases. It belongs to the "non-functional karstic systems" which possesses a large storage capacity due to a complex drainage structure partly or totally flooded with significant residence times. However, the paleo-conduit systems existing in the phreatic zone remain partly functional.

Proven methods exist to analyze karstic systems that are different from those of porous media, allowing the exploitation, management and protection of karst water resources. The management of Big Spring karstic system should be based on the analysis of aquifer functioning and groundwater monitoring in the spring vicinity. This type of approach should be generalized to karst springs throughout continental U.S.
Track Classification: Topic 7 - Karst Hydrogeology
The deep Maastrichtian aquifer belongs to the Senegalese basin and bears considerable groundwater resource. This system outcrops in the Diass horst zone, is composed of sandstone formations with mean thickness of 250-300 m. It is tapped by several hundred boreholes pumping at rates between 50-200 m³/h for human consumption, agriculture, pastoral and industrial needs. It is characterized by a general flow pattern (SE – NW), and the recharge zone is thought in the contact with the basement rock in the SE, in the East with the Senegal River, in the west at the Diass Horst and probably at Bissau Guinea. Since the 70s, the system has been subject to numerous investigations to understand its functioning, recharge processes as well as origin of high Cl and F in the central saline band.

Computed residence times from the detectable 14C range from 10,000 to more 30,000 yr evidencing palaeorecharge in the hydraulic system. Very low 14C (close to detection limit) and few 36Cl data reveal age of more than 250,000 yr. However high 14C values reveal recharged young water in the Northern part of the basement rock contact. These contents rapidly decay to low values at a short distance evidencing low to non-laminar circulation pattern in this region. Toward the West at the Diass horst zone, detectable 14C between 2-66pcmc are mainly due to high abstraction for urban water supply which create an imbalance in terms of water budget in the system and continuous lowering of the water table, which is presently at more than 35 m.

Radiocarbon data distributed throughout the system and O/H stable isotopes indicate old to very old water which was replenished under different climate conditions. Rapid decayed 14C in the supposed recharge zone and detectable radiocarbon in the horst zone are an indication of dynamic flow patterns which are thought to be convective and/piston type accompanied by dynamic influenced by high pumping in parts of the system. Despite these findings, some scientific issues need to be further investigated in order to build a conceptual model of the system functioning.

Considering the stable isotopes, distributed statistical values reveal different patterns with high range occurring in the East, saline band and West while lower range characterized the South and the heart of the system. Plotted in the conventional 18O/2H graph, values scatter along the meteoric line with an absence of evaporative effect. The higher range depicted in the eastern part of the aquifer should infer either by different climate recharge period or by circulation pattern which can be through Piston and/or convective flow. In the saline band and the Horst, differentiation in isotopic contents can derive from inflow of high pumping in boreholes operating in these areas.

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**Session Classification:** Parallel

**Track Classification:** Topic 1 - Groundwater assessment and management
Natural arsenic contamination of groundwater represents one of the most impacting environmental and health issues in several regions of the world, particularly in South and Southeast Asia, where millions of people may be drinking water with unsafe arsenic levels. In the densely populated region of the Red River Delta in Vietnam, water-quality data have shown the occurrence of arsenic concentrations above the WHO guideline value of 10 μg/L in both the shallow Holocene and deep Pleistocene aquifers.

Although previous studies considered the chemical conditions as a main proxy for arsenic contamination, this scenario has led to hypothesize a human-influenced contamination mechanism in deep aquifer.

It was demonstrated that the excessive groundwater pumping, due to the high water demand in intensive urban areas, can contribute to the quality deterioration of the Pleistocene aquifer triggering the compaction of interbedded clays and the subsequent expulsion of water containing dissolved arsenic or arsenic-mobilizing solutes.

To get a better understanding of the presence of arsenic in the deep aquifer and of the clay-compaction mechanism, the Weights of Evidence (WoE) Bayesian-based model was considered a reliable methodology, allowing to quantitatively evaluate the spatial correlation between arsenic pollution and factors potentially influencing the occurrence of elevated arsenic concentrations. These factors include: i) geochemical parameters (redox potential and iron concentration) in the Pleistocene aquifer, ii) arsenic concentration in the Holocene aquifer and iii) urban change patterns. The latter factor was expressed by using satellite QuikSCAT (QSCAT) data processed with the innovative Dense Sampling Method (DSM) to quantify urbanization in terms of building volume patterns and their rates of change in a decadal time span.

A direct correlation was found between arsenic contamination in the Pleistocene aquifer and: i) negative values of redox potential and ii) high iron concentration in the deep aquifer, iii) high arsenic concentration in the Holocene aquifer and iv) highly urbanized areas.

All these factors were combined to generate a predictive probability output, expressed as susceptibility map of the Pleistocene aquifer to arsenic contamination. The performance of this map was evaluated through the application of the same procedures adopted in previous groundwater vulnerability studies.

The relationship between high arsenic concentration and chemical parameters detected in the deep aquifer has proved to be consistent with the outcomes derived from the analysis performed in other works. The analysis on DSM data indicates that the excessive groundwater pumping can induce a vertical downward migration of chemical components and/or transport of arsenic contaminated waters from the shallow to the deep aquifer, determining the release of dissolved arsenic stored in deep interbedded clays into adjacent aquifers due to clay-compaction. These results provide preliminary information on the nature of deep groundwater arsenic and on the sources responsible for its mobilization.
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**Session Classification:** Parallel

**Track Classification:** Topic 5.3 - Advanced modelling tools for subsurface hydrology: from the vadose zone to deep environments
IMPACTS OF LAND-USE CHANGES AND URBANIZATION ON COASTAL GROUNDWATER RESOURCES OF LAGOS, SW-NIGERIA: Integrated Hydrogeochemical and GIS-based Assessments

Monday, 23 September 2019 12:30 (15)

Water and food security are essential to human survival and well-being vis-a-vis sustainable resources management and attainment of the SDGs. This study employed hydrogeochemical and GIS-based assessments of impacts of land use and urbanization on groundwater with emphasis on the resilience and security of coastal water supply in Lagos metropolis, SW-Nigeria.

For the assessment of land-use changes and associated impacts on community livelihood, Spot 5 satellite imagery of 1984, 2002 and 2017 of Lagos area alongside with Landsat ETM+ and OLI were used to generate the land use / land cover (LULC) changes in ArcGIS 10.3 Software. For the hydrogeochemical quality assessment, seventy (70) water samples were collected from different household water points (wells and boreholes) within Lagos. In-situ physicochemical parameters (pH, Temperature, TDS and EC) were measured in the field followed by laboratory analyses of major cations and anions.

GIS-based assessment revealed a significant increase in the built-up areas from 447.3km2 in 1984 to 951km2 in 2017 representing 85% increase with corresponding loss of about 5% of the forested coastal wetlands. This is a clear indication of rapid urbanization in the last three decades with attendant impacts on coastal water quality and sustainability. Hydrochemical assessment revealed elevated electrical conductivity (EC) of >1,000μS/cm alongside with elevated Na (51-230mg/l), Cl (300-980mg/l) and SO4 (36-88mg/l) concentrations in shallow wells and boreholes tapping the upper unconfined aquifer. This is a clear fingerprint of groundwater vulnerability to saline intrusion and contamination.

Therefore, in the face of reality of impacts of anthropogenic land-use and climate-induced changes, there is the need for a clear governance structure to regulate the rate of groundwater abstraction and indiscriminate groundwater development to ensure sustainable groundwater resources management and attainment of SDG-6 and avoidance of water supply crisis. Such crisis can be avoided, if appropriate knowledge-based choices, planning / management options are employed; failure of which will likely be very costly.

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Session Classification : Parallel

Track Classification : Topic 3.1 - Groundwater and water security in developing countries
Application of Na-Ca-Cl-Br Systematic in the Evaluation of Sources of Salinity in the Saline Groundwater Systems of the Benue Trough, Nigeria

Over the years, research community has been in search for a valid phenomenon to explain the occurrences of saline groundwater and brines within the evaporate-deficit but shale rich sedimentary units of the Benue Trough, Nigeria (BTN). Thus, this study is an attempt at unraveling the origin and possible diagenetic reworking of the primary saline source as precursor of saline groundwater occurrences in the BTN, using Na-Ca-Cl and Na-Cl-Br systematics.

Due to the prominent surface occurrences in the Lower and Middle Benue Trough, thirty-eight (38) saline groundwaters and brines samples were collected alongside in-situ determination of physical parameters using a portable hand-held multi-parameter meter while laboratory analyses of major cations and anions were undertaken using Inductively Couple Plasma Atomic Emission Spectrometry (ICP-AES) and Ion Chromatography (IC) methods respectively at the ACME Laboratories, Vancouver, Canada.

The average electrical conductivity (EC) values are 55,929μS/cm and 31,965μS/cm and total dissolved solids (TDS) values are 36,354mg/l and 20,777mg/l in the Lower and Middle regions respectively. These variations in EC and TDS indicate variable dilution or mixing event in the two regions as laboratory analyses and interpretation revealed Na-Cl dominated type of fluids. Hydrochemical evaluation of the chemical elements indicates significant enrichment in Ca²⁺, Sr²⁺, and Cl⁻ and depletion of Na⁺, Mg²⁺, K⁺, HCO⁻3, and SO⁴²⁻ relative to seawater values, attributed to subsurface intereactions with geological materials. Furthermore, rCl/Br and rNa/Br inferred two origin to the salinity as; halite precipitation and halite dissolution sources. However, the excess-deficit plot (Na-Ca-Cl) revealed seawater origin and modification in the original chemistry of the fluids in the order of 2 Na for 1 Ca exchange reaction, responsible for the enrichment in Ca²⁺ with a corresponding observed depletions of Na⁺; this enrichment-depletion patterns accompanying the salinity increases were mostly attributed to albitionization of plagioclase feldspars as the major dia-genetic reaction rather than dolomitization.

In summary, these saline groundwater and brines in the Benue Trough were actually seawater and dissolved halite originated; however, possible reworking / modification abound via interaction with the geologic materials and environments as a result of compaction of compressible sediments in the Trough during the tectonic episodes that affected the Trough.

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Session Classification : Poster with refreshments
Track Classification : Topic 3.1 - Groundwater and water security in developing coun-
tries
Evaluating sensitivity and uniqueness of underdamped slug test models for fractured rocks

Tuesday, 24 September 2019 15:15 (15)

Slug tests are one of the most common field methods for estimating local hydraulic properties, for fast and low-cost characterization of aquifer heterogeneity. In highly permeable fracture zones, underdamped responses, identified by oscillations of the water level, are generally observed. Several analytical and numerical solutions have been developed for modeling underdamped slug test responses. However, difficulties of interpreting data in fractured rocks from such tests are generally encountered because the complexity of the system raises the question of the choice of the appropriate model. In order to gain more insights about the fundamental problem of uniqueness arising with slug test analyses in heterogeneous media, sensitivity and uniqueness analysis of three transient-flow models of underdamped slug tests is proposed. As different flow geometries may be encountered in fractured rocks, we propose to evaluate solutions for linear, radial and spherical flows including inertial and wellbore skin effects in a fully penetrating well. As expected, the results from sensitivity analysis show that the hydraulic conductivity parameter is the most sensitive parameter regardless of model configurations. However, the sensitivity to aquifer storage is important for the linear flow case, less important for the radial case and negligible for the spherical case. The wellbore skin is also not negligible and must be considered. The uniqueness analyses show that underdamped responses are challenging to interpret as different flow geometry may fit the data, which results in different estimation of the permeability.

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Session Classification : Parallel

Track Classification : Topic 5 - Tools, methods and models to study groundwater
Traces of World War I in groundwater: perchlorate contamination of the chalk aquifer in NE France

Friday, 27 September 2019 12:15 (15)

Perchlorate is an environmental contaminant of growing concern due to its potential human health effects and widespread occurrence in surface water and groundwater. It is considered potentially toxic even at low concentrations (> 4 ppb) as an endocrine disruptor, especially for fetuses and infants. Analyzes have highlighted presence of perchlorate in drinking water of Champagne-Ardenne (NE France) with two suspected sources: a military source related to the WWI (World War I) and an agricultural one related to past use of Chilean nitrates.

In order to define the origin and fate of perchlorate in groundwater, a study area of 500 km² has been selected east of Reims, where drinking water catchments of the chalk aquifer are concerned with perchlorate contamination. Chalk groundwater flow and geochemistry are monitored for 2 years from June 2017 to June 2019 at 35 sampling points including boreholes, springs and rivers (mainly form chalk aquifer drainage). Water samples are collected monthly to determine the major and trace elements contents, stable water isotopes, perchlorate and organic pyrotechnic molecules. Perchlorate were detected at almost all sampling points (32 of 35) with a maximum value of 63 ppb and an average value of 11 ppb. High levels of perchlorate (> 4 ppb) were detected mainly downstream of the Monronvilliers military camp, where quantities of ammunitions were used, stored and destroyed during and after the WWI. Statistical analysis shows no significant correlation between perchlorate and other major ions. The isotopic signature of perchlorate was analyzed and showed a synthetic origin, proving for the first time the military source of contamination in this area. In addition, groundwater dating using CFCs and SF6 indicated an average residence time of < 30 years, implying that perchlorate contamination is related to sources that may still subsist in the subsoil after the WWI (e.g. unexploded ammunitions) rather than military activities during the conflict. Perchlorate concentrations are relatively stable with time for most points except for decreases observed in September 2017 and 2018. Stable isotopic analysis of water and monitored groundwater table showed that the chalk aquifer is recharged by precipitation mainly during the winter season. Therefore, the decrease of perchlorate levels could possibly be explained by the very few recharge and low groundwater table in September, as less perchlorate is dissolved and transferred into the aquifer. This research provides insights on a combined use of hydraulic, geochemical and isotopic approaches to study the origin and transfer of contamination in chalk groundwater. The chalk aquifer properties and the long-term influence of the WWI on groundwater quality in NE France are better clarified, with the aim to provide appropriate recommendations in terms of water management.

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Session Classification : Parallel

Track Classification : Topic 8 - Groundwater quality and pollution processes
THE PROTECTION OF SPRINGS USED FOR HUMAN WATER SUPPLIES. A CASE STUDY BASED ON MULTI-CRITERIA EVALUATION

Monday, 23 September 2019 16:00 (60)

The problematic that commonly arises when protecting springs that supply water for human consumption requires a methodological method to prioritize springs that are used for this purpose according to the greatest need for protection from contamination and exploitation processes. The present study proposed the application of a method to prioritize springs in order to facilitate the sustainable management of springs that urgently need protection.

The stages included in the method were: a) regionalization of the study area considering physical variables, which included precipitation, hydrogeological functioning, and slope of the terrain; b) selection of the springs used for human supply that have the greatest exploitation flows and c) prioritization of springs to be protected based on a multi-criteria evaluation (MCE), considering criteria such as exploitation flow, land use, population to be supplied, conservation of spring water collection systems, existence of alternative supply sources, and marginalization index of nearby populations. Using MCE (through the AHP), it was possible to analyze the different criteria based on the opinion of experts, thereby considering different points of view when assigning a weight to each criterion. The methodological process was performed with the help of geographic information systems (GIS). The study case was the State de Mexico. The National Water Commission (CONAGUA, 2015), a government agency responsible for managing water resources, has 2,937 water use permits registered for the use and exploitation of springs. Of the total springs, 1,997 (67%) are used for human consumption, with an exploitation volume of 94,869,976 m³/year (34.5% of the total allocated volume). These springs are used particularly by rural and semi-urban communities. Regionalization enabled identifying regions that were homogeneous in terms of the characteristics of the springs and their physical environment. Six of those regions with the largest territorial areas were selected, where 88% of the springs used for human consumption were located. Within each selected region, the springs that were representative of exploitation flow were identified, and a total of 23 were included. Lastly, MCE was applied to identify six springs (one in each region) that were priorities for protection. The prioritization of the springs to be protected in each of the six regions selected will facilitate the future application of protection methods based on the physical characteristics of the springs and their physical and socioeconomic environments.

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Session Classification : Poster with refreshments

Track Classification : Topic 1 - Groundwater assessment and management
Interpretation of a large scale pumping test conducted in faulted sedimentary rock from channel type flow structures

Tuesday, 24 September 2019 15:45 (15)

Well tests performed in fractured rocks often display non-classical drawdown behaviors due to strong hydraulic heterogeneity and various flow structures investigated. Such signals are thus challenging to interpret but contain important information on flow-bearing structures (i.e., hydraulic heterogeneity and connectivity), particularly useful for site understanding and modeling. We propose here to interpret a large-scale pumping test performed in a major fault zone developed in an inter-bedded sandstone shale sequence of turbidite origin. The pumping test was carried out over 31 days and responses were recorded up to 725 m distance from the pumping well. Successive and different flow regimes are observed at the pumping well and are consistent with channel type flow structures. As a guideline, synthetic well tests were simulated for several idealized channel configurations. This numerical investigation shows that similar drawdown responses may be obtained for different channel configurations and properties, which highlight the problem of uniqueness and uncertainty on hydraulic properties. Such problems may be partly reduced with the number of observation wells properly distributed and geological information to constrain the interpretation of a single realization. The interpretation of the real experiment is then proposed consistent with drawdown observations and geological structures, and limitations are discussed based on available information.

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Session Classification : Parallel

Track Classification : Topic 5 - Tools, methods and models to study groundwater
Hydrogeological aspects of the northeast part of Yucatan Peninsula by the use of noninvasive geophysical methods

Thursday, 26 September 2019 16:00 (60)

The major aquifer of the Yucatán Peninsula (YP), a highly permeable, fractured limestone (karst), allows rapid transport of microbial and chemical contaminants to the subsurface, resulting in significantly increased potential for groundwater pollution. Knowledge of the functioning of an aquifer is vitally important for its use, protection and sustainable exploitation. Among the tools, that we can use to predict this behavior is the simulation of groundwater flow, in which it is to describe the physical phenomena involved. The construction of the conceptual model is the first step to perform the simulation based on information obtained from geophysical, geologic and hydrogeological techniques. This paper presents preliminary results of the data obtained in the field for mapping the depth to the saline water that underlies the fresh-water aquifer at the northeast part of YP.

The rise in tourist activities that increase the developments at the northeast part of the YP especially those related to small village were the exponential growth of the economic activities result in the rise of groundwater pumping and pollution treat. This assessment included mapping the water table, the stratification of the water column in fresh/saline; and identification of the flow pathways near sinkholes and along "Ruta de los Cenotes", Puerto Morelos Q.Roo (YP). Noninvasive geophysical methods were used: a Schlumberger resistivity sounding and the transient electromagnetic method (TEM) were used to estimate depth to the fresh/salt water interface. Spontaneous potential (SP) geophysical identified karst conduits where water could percolate downwards in the vadose zone. Results suggest that water table varies from 1 m at the coast to 6 m depth 27 Km inland; a Time domain electromagnetic soundings suggest fresh/saltwater interface varies from 38 to 45 m depth. Preferential flow paths were identified using resistivity profiling and spontaneous self-potential (SP) geophysical methods.

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Session Classification : Poster with refreshments
Track Classification : Topic 7 - Karst Hydrogeology
Multi-fractal model for analyzing seepage parameters of fractured rock mass

Tuesday, 24 September 2019 16:00 (60)

The fractured rock mass is complex in structure and variable in morphological parameters. Due to lack of effective techniques for direct observation of internal water flow in fractures, accurate calculation of three-dimensional permeability parameters of rock mass still remains a scientific problem. The single fracture seepage is related to the crevice fluctuation and the opening degree. The seepage in the spatial fracture network is related to the fracture communication. Based on the actual measurement of fracture morphology, this study proposes a multi-fractal model for analyzing seepage parameters of fractured rock mass. Firstly, the single-fracture wall is scanned by a three-dimensional laser to obtain the fractal dimension of the closed or open fracture surface morphology. Combined with the cubic law and Darcy’s law, the single-fracture water flow is analyzed, the fractal dimension of the water flow path is calculated, and the fractal relationship between the single fracture morphology and the permeability coefficient is obtained. Then the three-dimensional fracture communication network is established by Monte Carlo method, and the two-dimensional fracture communication network in different directions is obtained through orthogonal slice. The fracture communication is described by the fractal dimension of the fracture density, and the fractal dimension of the two-dimensional and three-dimensional fracture network communication rate is established. Finally, the two-dimensional fracture seepage path and permeability coefficient are analyzed according to the undirected graph adjacency matrix and continuity equation of seepage, and the three-dimensional seepage flow coefficient of the fractured rock mass is solved by the fractal dimension of the two-dimensional and three-dimensional connectivity. The model realizes the analysis of the permeability parameters of the fractured rock mass by the fractal dimension of the fracture and the seepage analysis of complex fracture networks is conducted by step-by-step dimensionality reduction from three dimension to one dimension, which provides a new idea for the study of fractured rock mass hydraulics.

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Session Classification : Poster with refreshments

Track Classification : Topic 5 - Tools, methods and models to study groundwater
Assessing emergent contaminants as anthropogenic markers and its fate in aquatic ecosystems at Yucatan Peninsula

The Northeast of Yucatan Peninsula; Mexico; due to its natural resources: beaches, jungles, sinkholes, reef is one of the main Mexican tourist poles. Presenting one of the most accelerated growth is recreational activities and in consequence the rise of development on the coast and inland. Moreover, this region underlies a vulnerable karstic coastal aquifer at the Yucatan Peninsula, high permeability fractured limestone, which allows rapid transport of contamination resulting in a significant potential increase of pollution affecting the ecosystems.

Several studies indicate the importance of chemical markers to track pollution by domestic and industrial activities. Potential candidates are endogenous metabolites released by the human body and components of pharmaceutical products, personal care products and food. Regular and constant consumption is a prerequisite for the selection of a good marker, which implies that consumer habits do not change or change gradually in the coming years. Caffeine has been used as a chemical marker of the water quality to improve the accuracy with which are detected polluting sources of domestic origin. Caffeine occurs mainly in beverages such as coffee, tea, some bottled drinks (sodas) and some drugs for human consumption.

This work summarize three evaluations of caffeine along with bacteriological quality and the toxicity to the ecosystem. Caffeine was used as an emerging contaminant as a marker to identify the sources of pollution and its impact on groundwater (wells, sinkholes and lagoon). The detection of caffeine to points of high presence of bacteria E. coli, can confirm that the alteration of the water quality in some of these sites has a direct connection with the tourist type anthropogenic activities. While the presence in the area of extraction wells is due to infiltration of untreated or semitreated wastewater water, moreover presence of caffeine was also detected at the lagoon where only rural and domestic activities characterize the area, the toxicity evaluation by zooplankton indicated an impact in the aquatic biota.

The importance of these results indicated that presence of contaminants might not be related to the increase or the size of the human developments but the lack of wastewater service that represent a potential impact to the aquatic ecosystems.

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Session Classification: Parallel
Track Classification: Topic 8 - Groundwater quality and pollution processes
Interbasin water transfer with groundwater. The Lerma Wells System for the supply in the metropolitan area of Mexico City

Thursday, 26 September 2019 16:00 (60)

The Upper Basin of the Lerma River is located in the region known as the Mexican Altiplano and is an important center of industrial and agricultural activities; as a consequence, this basin has suffered an increase in the number of its inhabitants with the consequent increase in the needs of drinking water that is covered with groundwater. To this fact, we must add the import of groundwater carried out by the metropolitan area of Mexico City (Basin of Valley of Mexico) to cover its human supply needs. The extraction is done through the Lerma Well System (250 wells). This system of wells has come to extract a maximum flow of 14 m3/s, flow that is currently 5m3/s, and that represents approximately 8% of the total flow with which this metropolitan area is supplied. These wells are in the aquifers of the Toluca Valley and the Atlacomulco-Ixtlahuaca Valley. Of these two valleys, the one that is subject to greater exploitation of its waters is the Valley of Toluca. The effects that have caused this exploitation are the object of study of this research. In particular, the economic effect caused by increased energy consumption was studied by having to pump water at greater depths due to the decrease in the groundwater table level and the impact caused by the appearance of cracks caused by land subsidence.

The impact of the cracks in the aquifer was assessed through the study of the vulnerability of the aquifer to pollution. The vulnerability determined with the SINTACS method has shown the increase in the degree of vulnerability (from Low to High) in areas where cracks were identified. To measure the economic impact due to abatement of the groundwater table level, maps of isocost curves were drawn up, which allowed to appreciate that the region most susceptible to increasing the costs by pumping is the central zone (where the city of Toluca is located), while in the west of the aquifer, there is a greater tendency towards energy savings and, therefore, costs.

It is important to design pollution monitoring and control strategies and establish a monitoring of the cracking zones in order to avoid unnecessary dangers to the population. The cost increases should guide the definition of the potable water tariff system and the determination of the type of industry with potential to settle, privileging those of low water consumption but high added value and generation of jobs with qualified labor.

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Session Classification : Poster with refreshments

Track Classification : Topic 9 - Groundwater and socio-economic development in Latin-
Development and application of recharge models for irrigation areas with perched water tables

Tuesday, 24 September 2019 16:00 (60)

Perched water tables are often associated with irrigation areas overlying a low-conductivity layer. Perching leads to waterlogging and salinity, necessitating sub-surface drainage. It also affects water percolating below the impeding layer to the regional water table, through changes in magnitude of fluxes and timing of impacts at the water table. In this way, perching affects the growth of groundwater mounds, and associated increases in salinity in nearby land and streams. The degree of perching, and risk of salinity, are reduced by water use efficiency improvements. The residual risk from irrigation development and efficiency improvements is determined by both the magnitude and timing of impacts.

Salinity strategies for the Murray-Darling Basin in south-eastern Australia have reduced salinity in the River Murray by developing salt interception schemes and the encouragement of water use efficiency programs. Groundwater modelling along the lower stretches of the River Murray is used to guide design and management of groundwater pumping, attribution of costs and rehabilitation of floodplains, but does not currently simulate perching and its influence on the magnitude and timing of salinity impacts to the river, creating a gap in the modelling process between cause and effect.

This talk describes the trialing of integrated agronomic-unsaturated zone-groundwater modelling at Loxton, which represents perched water tables explicitly and links the relevant processes. The agronomic water balance model uses observed diversion volumes and empirical parameters to estimate a time series for irrigation accession flux. The unsaturated zone model uses this time series to estimate the time series for recharge and losses to the surface (mainly by drainage). The groundwater model uses the recharge output as part of estimating fluxes of groundwater to the River Murray and adjacent floodplains and groundwater pumping schemes. The magnitude and timing of the groundwater flux is directly related to the magnitude, timing and location of irrigation recharge, which, in turn, is directly related to the empirical factors and the thickness and properties of soil layers. Some of these parameters, along with hydrogeological parameters are difficult to measure at scale and need to be calibrated in a way that constrains non-uniqueness problems. The purpose of the trial is to develop approaches for the implementation and calibration of the integrated model.

The development of the unsaturated zone model that can adequately represent perching has been critical to the capacity to conduct such a trial. While numerical models, can simulate unsaturated zone processes, including perching, numerical stability and the temporal and spatial complexities of irrigation areas mean that such models are impractical. A quasi-analytical model, benchmarked against FEFLOW, has been developed to represent these processes and could be used in modelling applications elsewhere.

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Session Classification : Poster with refreshments

Track Classification : Topic 5 - Tools, methods and models to study groundwater
Geochemical evolution of deep groundwater in the Southern Gobi Region (SGR) of Mongolia

Increasing water demand needs an integrated water resource management and assessment in arid and semi-arid regions. One of the biggest examples is the Gobi Desert, which expands across northern China and the southern part of Mongolia, and it is one of the largest cold deserts in the world. The issue of unsustainable water use for irrigation has been recognized in the southern part of the Gobi Desert (northern China) but water usage is increased significantly by mining industries in the northern part of the Gobi Desert (southern part of Mongolia) during the past decades. Groundwater serves as the only source of water supply and is hugely utilized by mining companies such as the Tavan Tolgoi and Oyu Tolgoi Mine located in the SGR. The area is expected to face severe water shortages of mining and drinking water, which may be related to changes in groundwater recharge due to climate change. Understanding the geochemical evolution of groundwater and recharge mechanisms in the Gunii Khooloi aquifer is thus paramount for water resource management in this region. However, chemical compositions of groundwater in the SGR has not been studied so far. In this study, the hydrogeochemical approaches have been introduced to characterize geochemical evolution and hydrogeochemical characteristics of deep groundwater in the SGR. Deep wells in the Gunii Khooloi aquifer were sampled (in September 2016, and in June 2017) for major chemical analysis in order to understand the general hydrogeochemical conditions of the study area. The results show that deep aquifer is classified as Na-Cl type with high EC, and silicate weathering, dissolution of albite, calcite, gypsum and trona are the main geochemical processes in this region. However, dolomite and halite dissolutions are not considered to occur in the study area.
Hydrological characterization of Maullín river basin

The knowledge of the hydraulics and the intrinsic properties of the hydrogeologic units is fundamental for the sustainable use of the hydric resource in a basin. The objective of this study is to accomplish an integrated analysis of the hydrologic system of the Maullín river basin (a lacustrine basin covering approximately 4,300 km²), focused on determining the dynamics of groundwater and the properties of the materials where the water flows. It was developed on the basis of geology, geophysical prospecting and water well information (referring to its stratigraphy and pumping tests), which define the hydrogeologic units and the piezometry, from which groundwater flow is deduced. From the integration of the information it was established that the hydrogeologic units of high potential for water extraction are of granular type and are found, mainly, in sedimentary deposits of the Pleistocene-Holocene of glacial and glaciofluvial origin, harboring confined and unconfined aquifers. These units are connected to each other, so they can be considered as a large aquifer system. The very low hydraulic conductivity units are associated to the metamorphic rocks of the Paleozoic-Triassic and to intrusive rocks with granitic composition of Oligocene-Miocene, which constitute the impermeable basement. Based on the information from the water wells, an analysis was carried out on 233 pumping tests, obtaining estimates of their transmissivity. The results showed a maximum of 9,480 m²/day and a minimum of 0,8 m²/day. The statistic analysis of the transmissivity allowed to compare the water extraction capacity of the different units and to define the characteristic ranges of the most important ones. The storage coefficient could be estimated from a single pumping test that had record levels in an observation well, which resulted in a value of 0,002.

The basin piezometry is closely related to the surface morphology, where the topographic highs coincide with the areas with the highest elevation in the piezometric surface. This condition indicates that the main source of recharge of the aquifer system has its origin in rainfall and that the relationship between the Maullín river and its main tributaries, with the aquifer system is of the effluent river type. In addition to this, the piezometry shows a lateral outlet at the south of the basin.

With the information given by the piezometry and the hydraulics properties of the hydrogeologic units we can conclude that the water received by the soil and the vegetation cover, is divided into a evapotranspiration, surface runoff and a third component that infiltrates to join the aquifer system. The main outlet of groundwater is the discharge to the bodies of surface water, to which are added: the water extractions by pumping wells and the lateral outlet of the basin.
Source analysis of sediments and leakage water in corridor of underground reservoir in Karst area

Thursday, 26 September 2019 16:00 (60)

Underground reservoir in Karst area is a very special type of reservoir. It is constructed considering the characteristics of Karst stratum and topographic structure. It realizes the functions of reservoir such as water supply by retaining groundwater or underground river. Because of the development of fracture in Karst area and the solubility of limestone and cement of grouting, leakage water and some sediments are common in reservoir corridors. To investigate the source of leakage water and sediments, Tsinghua Tung Reservoir, located in the Karst area of Southwest China, was taken as an example. Firstly, the sediments were taken in the upper and lower corridors of the reservoir and analyzed by thermogravimetry and XRD. The results showed that the mineral of the sediments was only CaCO3 and there were no other minerals, a typical product of chemical process. It meant that the sediments came from the dissolution and re-precipitation of limestone and grouting curtain. Secondly, in order to find out the source of leakage water in the corridor, the reservoir water, rainwater and leakage water were sampled and analyzed separately. The results of hydrochemical diagram showed that there were significant differences among these water samples. Based on the analysis of hydrogen and oxygen isotopes and the results of hydrochemical model, the leakage water mainly came from the reservoir water and was little affected by rainfall.

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Session Classification : Poster with refreshments

Track Classification : Topic 7 - Karst Hydrogeology
Evolution simulation of karst groundwater flow field by considering multi-year time series (1959-2018) recharge and drainage changes in the Jinci spring area, China

Thursday, 26 September 2019 16:00 (60)

The Jinci spring is a famous karst spring in north China. From 1954 to 1958, its flow rate was relatively stable with an average flow rate of 1.94m3/s. The Jinci spring was cut off in 1994 due to the long-term overexploitation of karst groundwater in the spring area. After the cut-off, the water level near the spring outlet continued to decline, and the maximum depth to the spring outlet in 2008 reached 27.76m. After 2008, the local government took a series of comprehensive rectification measures, and the water level gradually rose. At the end of 2012, the water level at spring outlet quickly recovered, with a depth of 11.96m. In February 2019, the water level was 1.8m depth to the spring outlet.

In this paper, based on multi-year time series data for the recharge, runoff flow, and discharge of groundwater in the Jinci spring area, the attenuation of Jinci spring and the changes of regional flow field were analyzed by using multiple regression analysis and artificial neural network model. It was concluded that the factors, such as precipitation, leakage of the Fenhe river, the exploitation of karstic groundwater as well as coalmines discharge, affected the flow of Jinci spring. The water discharge from the coalmine and groundwater overexploitation are the essential factors which result the spring cutoff. Then, on this basis of the equivalent continuum porous model(EPM), a three dimensional heterogeneous anisotropic model coupling with the preferential flow along strong runoff zone was built to study the evolution of regional karst groundwater system, in which several special modules such as nonlinear processes of rainfall infiltration and river leakage, the artesian well and spring, and karst groundwater exploitation from the coalmine were integrated. The karst water model was verified by using long-term monitoring data for hydraulic head fluctuates in the different area of spring domain. After the data of rainfall rate, the history of groundwater exploitation and coal mining, and the implementation of water-conservancy project in the multi-year time series are input into the model, the model was running to reproduce the evolution process of regional groundwater flow field in the recent 50 years, and further reveal the cause of the attenuation of the Jinci spring and the rise of the water level near the spring outlet in recent years.

Besides, the karst groundwater model is used to evaluate the efficiency of different schemes under various water replenishment measures for the reflowing of the Jinci spring, and predict the evolution tendency of regional flow field, so as to provide a scientific basis for the Jinci spring recovery.

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Session Classification : Poster with refreshments
Track Classification: Topic 7 - Karst Hydrogeology
Tourism development requires supporting water resources, yet often lacks sufficient hydrogeological knowledge to guide water management and development steps. The Government of Haiti (GOH) has identified tourism as a strategic initiative to stimulate growth of the national economy and has targeted the southwest coast of Haiti based on its beaches, mountains, and tourism potential. Initial planning for a proposed 5,590 ha eco-tourism zone in the region led the Haiti Ministry of Tourism and International Financial Institutions to evaluate water resources and water security to determine the feasibility of supplying 5,300 m3/day of water from a locally known aquifer with current agricultural and domestic demands. Aquifer characterization and groundwater modeling led to the determination that the Bwa Dom aquifer could not sustainably support the integrated demands of the proposed eco-tourism zone and existing irrigation and domestic demands. The technical analysis led to the creation of alternative development concepts more integrated with the regional hydro-scape, thereby preserving renewable resources to enable the growth of the local agricultural economy in parallel with eco-tourism development.

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Session Classification : Parallel
Track Classification : Topic 9 - Groundwater and socio-economic development in Latin-America
AN ANALYSIS OF RIVER MORPHOLOGY ON FRESHWATER LENS DYNAMICS IN ARID/SEMI-ARID REGIONS

Tuesday, 24 September 2019 15:30 (15)

Understanding the complex interaction between groundwater and surface water (SW-GW) is essential for effective management of water resources. One of the most important results of this interaction is formation of freshwater lenses. Terrestrial Freshwater Water Lenses (TFWLs) are of great importance in areas with regionally-extensive brackish to saline groundwater. When recharge occurs through rainfall or river or lake, a TFWL will form, with freshwater floating above denser, saline groundwater derived from the sea or underlying aquifer. TFWLs in arid and semi-arid regions are critically important for the health of threatened ecosystems, and provide other positive functions within otherwise semi-arid and arid riparian settings. TFWLs have been described as some of the most vulnerable aquifer systems in the world, which can be attributed to various factors, such as episodic droughts, excessive pumping and river flow manipulation.

This study aims to quantify the potential impacts of river morphology on formation of TFWLs at an arid setup with saline floodplain aquifer. A series of river morphology scenarios are modelled based on river bank slope ranging from 90° to 15° from horizontal and meandering ranging from no-meandering to 3 bends for both gaining and losing rivers. A 400m by 800m, 10 m thick aquifer is modelled as homogeneous and isotropic with an impermeable base and constant head on the right and left hand boundary conditions and variable heads at the river nodes. To represent the arid/semi-arid regions, constant values of 200 mm/year and 1000 mm/year were assigned for rainfall and ET, respectively. The soil parameters were based on sandy-loam from the soil types Carsel and Parrish.

The problem to be modelled involved both surface and porous media domains, therefore the fully-coupled, surface–subsurface flow model HydroGeoSphere is used. HydroGeoSphere simultaneously solves the diffusion-wave approximation of the Saint Venant equation for surface water flow, and the Richards’ equation governing 3D unsaturated/saturated subsurface flow with a physical coupling between the two domains.

The results of this research demonstrate the significant impacts of the examined drivers on dynamics of TFWLs at saline arid setup. Increase in river bank slope, 90° to 15° from horizontal, may lead to larger TFWLs. Moreover, meandering pattern show significant impact on FWLs distribution at the floodplain aquifer. Overall, this study is a step forward towards better understanding of dynamics of TFWLs as one of the most valuable and vulnerable water resources.

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Session Classification : Parallel

Track Classification : Topic 5 - Tools, methods and models to study groundwater
A baseline assessment of emerging organic contaminants in New Zealand groundwater

Friday, 27 September 2019 12:15 (15)

To date, no baseline assessment of emerging organic contaminant (EOC) occurrence in New Zealand groundwaters has been undertaken. Recognition of the significance of EOC in NZ groundwaters is increasing but analytical capability remains limited. EOCs comprise an increasing number of compounds originating from a range of origin and use. EOCs ubiquitous occurrence in groundwater has been demonstrated in numerous International studies. The impact of EOCs on freshwater quality, human and aquatic health is yet to be characterised for most compounds. Where negative impact has been demonstrated, EOCs are selectively banned or restricted.

To inform future monitoring, we conducted the first regional EOC baseline survey in New Zealand groundwater using a novel sampling design: State of Environment (SOE) monitoring sites were selected randomly from a groundwater mean residence time (MRT) stratified site list. Forty-seven SOE sites representing young (1-11 yrs MRT), intermediate (11-50 yrs MRT) and old (50-250 yrs MRT) groundwaters were screened for a wide EOCs suite (723); including ten targeted sites located close to known EOC sources for comparison.

Five EOC categories were detected at 91% of the SOE sites: pesticides (48 compounds), pharmaceuticals (11), industrial (10), preservatives/food additives (3) and personal care products (1). EOC concentrations ranged from 0.1 to 11000 ng/L and were generally lower that those reported in overseas groundwaters. Concentrations above the EU maximum admissible concentration for total pesticides (100 ng/L) were measured at 28 SOE sites. Young groundwater exhibited higher EOC concentrations and a wider range of compounds, however detections occurred in all MRT groups.

Seven EOC categories were detected at targeted sites. The two categories found only at targeted sites were drugs of abuse and lifestyle compounds. Concentrations ranged from to 0.2 to 14000 ng/L. Pesticide concentrations were generally lower at SOE sites than at targeted sites, but concentration of other categories were higher at targeted sites.

The survey results were used to: review current pesticide monitoring; propose complementary monitoring; identify potential EOC groundwater tracers and identify compounds for which cost-effective New Zealand laboratory capability is needed.

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Session Classification : Parallel

Track Classification : Topic 8 - Groundwater quality and pollution processes
Field Survey on recovery situation from groundwater salinization that was brought by the tsunami of the Great East Japan Earthquake using a pumping device with packing

Objectives: In the coastal areas, which were damaged by the tsunami caused by the Great East Japan Earthquake in 2011, the salinity of the groundwater rose by infiltration of seawater. Currently, fresh water layer has been formed by rainwater during these 8 years after the tsunami on the top of the salt water layer in unconfined aquifer. The objective of this study is to clarify the possibility of reuse of freshwater in this area by field survey.

Design and methodology: The study area Watari district, located on the east coast of northeastern Japan, was damaged by the tsunami up to 5 km from the coastline. Pumping tests were carried out every three months in 19 monitoring wells between 2017 and 2019 in this area. The monitoring wells were made of PCV and had depths of 10 to 15 m and a diameter of 50 mm. Since saltwater was distributed in the deep part of the monitoring well, a packer was installed at the boundary between saltwater and freshwater in the pumping tests, and pumping was carried out above the packer. Each pumping test was carried out for 10 minutes and groundwater pumping ratio was 10-15 liter/minute. EC, pH, DO, and ORP of groundwater that was pumped were measured during the pumping.

Results and conclusion: At 9 out of 19 monitoring wells, the average EC of pumped groundwater was less than 70 mS/m, which was suitable for the cultivation of strawberries, a main product of this area. These 9 monitoring wells were located relatively far from the coast. These results show that groundwater quality has recovered from salinization at relatively far from the coast. On the other hand, in the monitoring wells relatively close to the coast, the EC of pumped groundwater was in the range of 70 to 200 mS/m, which was suitable for cultivating crops with high salt tolerance. In these wells, the EC of pumped groundwater tended to decrease as the installation depth of the packer decreased. These results show that the recovery of groundwater quality is slow in the area close to the coast, and it is necessary to reduce depth of well to obtain groundwater with low EC. However, even though they were located at relatively short distances, some wells had large differences in the EC of the groundwater being pumped. It is estimated that there are factors other than the distance from the coast that affect the degree of recovery from groundwater salinization.

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Session Classification : Poster with refreshments
Track Classification: Topic 5 - Tools, methods and models to study groundwater
Groundwater salinization mechanism in an arid inland basin: the Manas River Basin in the Northwest China

Manas River Basin (MRB) is a typical mountains-oases-desert arid inland river basin in the Northwest China. Its oases plain is an important economic agricultural production area. With the increase of population and land reclamation in the MRB, water shortage problem is getting seriously in the past decades. The continuous decline of groundwater level, groundwater salinization and environmental degradation are threatening sustainable development of the local economy. It is significant to understand the mechanism of groundwater salinization for water utilization, soil salinization controlling and environmental protection in the MRB.

Based on field investigation and system analysis of regional groundwater flow, surface water, aquifer groundwater and aquitard porewater in the MRB were collected and their hydrochemistry, stable and radioactive isotopes were measured. Soil water content, temperature and EC were monitored by using the 5TE sensors and soil evaporation rates were monitored by using the micro-lysimeters in the field. Artificial bromide tracers were used to evaluate groundwater evaporation rates. Soil column experiments and numerical simulation of flow and salt transport were carried out to understand the interaction processes of evaporation and salt accumulation.

The results show that the salinization or total dissolved solids of groundwater are different at different location of the MRB. The hydrogeochemical and isotopic characteristics revealed groundwater salinity in the piedmont area was low with fast freshwater infiltration and low evaporation. The average salinity increased along the groundwater flow paths because of mineral dissolution, evapotranspiration, and agricultural activities. Groundwater received modern water recharge from irrigation and channel leakage with flushed soil evaporites in the middle alluvial–diluvial plain. Direct evaporation occupied 1-59% of groundwater loss and contributed 0.14-49.85% to salinity in different aquifers at different location based on the deuterium excess method. The saline porewater released from aquitards due to overexploitation is an important factor for groundwater salinization of the middle and deep aquifers in the depression zone. The average evaporation rates of phreatic water between May and August of 2017 was 0.04-2.26 mm/day estimated by Bromide tracing. Evaporation rates reached up to the maximum value after precipitation. When soil water content reduced, the rates decreased in the desert area and non-saline soils. The low water content is the major factor that restricts soil evaporation rates. While in the saline soils, the salt content in the soils and salt crusts on the land surface reduce the soil evaporation rates. The results of soil column experiment showed that the solution concentrations affected the evaporation rates in saturated soils. The higher solution concentrations, the lower evaporation rates happened. Evaporation from saturated zone resulted in salt precipitates and salt crust on the soil surface. The evaporation rates increased at the early stage, and then slowed down due to the salts crust growth.

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Session Classification: Parallel

Track Classification: Topic 5 - Tools, methods and models to study groundwater
Identifying the groundwater flow systems in a condensed river network interfluve between the Han River and the Yangtze River using hydrogeochemical indicators

Thursday, 26 September 2019 16:00 (60)

Investigation of groundwater flow patterns is vital for the sustainable management and protection of water resources. Hydrogeochemistry and environmental isotopes were used to gain insight into the recharge process, water–rock interactions, and groundwater residence time and to accurately identify groundwater flow systems (GFSs) in an interfluve between the Han River and the Yangtze River in the eastern Jianghan Plain, an alluvial-lacustrine plain in the middle reaches of the Yangtze River. The Jianghan Plain is a semiclosed basin densely covered with rivers and lakes in the middle reaches of the Yangtze River in south-central of Hubei Province in China. The intensification of anthropogenic activities such as discharging domestic sewage and industrial wastewater as well as using pesticides and fertilizers has led to high levels of organochlorine and nitrate in groundwater. Furthermore, impeded drainage caused by lake reclamation has further exacerbated the water security problem.

The objectives of the present study were to gain insight into the recharge process, water–rock interactions, and residence time of groundwater on the basis of an investigation of hydrogeological conditions, hydrodynamic fields, and hydrochemical and isotopic indicators ($\delta^{2}H$, $\delta^{18}O$, $^3H$, and $^{14}C$ data); and ultimately acquire a conceptual understanding of GFSs pattern in an interfluve between the Han River and the Yangtze River. Hydrogeochemical and isotopic assessments of surface water and groundwater were conducted for the interfluve between the Han River and the Yangtze River in the eastern Jianghan Plain, a typical alluvial-lacustrine river basin in the middle reaches of the Yangtze River. The major findings of this study are summarized as follows.

The typical ions and isotopic distributions with depth indicate that the GFSs were divided into local and regional GFSs based on a limitation of approximately 20 m. That depth is attributable to complex anthropogenic activities, water–rock interactions and groundwater flow patterns. The distribution of $\delta^{18}O$ indicated three evident zonations in regional GFSs that are likely dominated by the altitude effect of recharge areas. Furthermore, multiple independent local GFSs exhibited a pattern in which groundwater discharged into surface waters during the nonflood season. The regional GFSs pattern is controlled by slow lateral flow from west or northwest to east, eventually discharging into the Yangtze River and the Han River. Groundwater age was estimated using radiogenic ($^3H$, $^{14}C$) isotope data and varied from the present to 5000 years, elucidating that the hydrodynamic circulation of local GFSs is active, whereas that of regional GFSs is slow to relatively stagnant. The hydrodynamic characteristics and hydrochemical distributions corroborated the occurrence of upward flow in the discharge area of regional GFSs in the Jianghan Plain.

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Session Classification: Poster with refreshments

Track Classification: Topic 5.4 - Innovative approaches for understanding groundwater flow systems
QUANTITATIVE CLASSIFICATION OF CARBONATE AQUIFERS BASED ON HYDRAULIC BEHAVIOUR

Thursday, 26 September 2019 12:00 (15)

While hydrogeological systems hosted in igneous rocks are typically considered as fractured systems, those hosted in carbonate rocks are traditionally considered as karst systems. Little effort has been made to quantitatively distinguish between well-developed karst systems and poorly karstified or fractured systems hosted in carbonate rocks. At the same time, there is an inconsistency in the application of investigation techniques. While most carbonate systems are proven to manifest karstic hydraulic behaviour, equivalent porous medium models are extensively used for simulating hydrodynamic and transport processes.

It is crucial to determine the hydraulic behaviour of strongly heterogeneous systems in order to select the most appropriate investigation techniques and modelling approaches.

While limestone aquifers usually manifest karstic hydraulic behaviour, dolomite aquifers represent an ambiguous group of carbonate rocks. While classical karstic landforms such as sinkholes or dry valleys might be present, they usually lack well-developed hierarchical conduit networks. Spring and well hydrographs contain important information about the hydraulic behaviour and geometric characteristics of carbonate aquifers. Analytical formulae have been developed to describe hydraulic behaviour and to quantitatively classify strongly heterogeneous systems based on hydrograph analysis.

The proposed method is demonstrated through the application of field data. Several test sites including limestone and dolomite aquifers have been studied through systematic spring discharge and piezometric level monitoring. Hydrograph analysis of flood peaks was undertaken to determine aquifer characteristics and to classify aquifer hydraulic behaviour. The results of hydrograph analysis were verified through field observations.

The proposed quantitative classification method provides crucial information about the hydraulic functioning of carbonate hydrogeological systems, and facilitates the selection of adequate investigation and modelling techniques.

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Session Classification : Parallel
Track Classification : Topic 7 - Karst Hydrogeology
Groundwater drought investigations – Case study from Pomurje (NE Slovenia) for period 1981 – 2016

There is no uniform definition for groundwater drought. The identification of the phenomena in literature is common defined by water deficiency in water body compared to normal water conditions (Sheffield & Wood, 2011). Slovenia is water abundant country and therefore the usage of the term drought often brings up the dilemma. Is it correct to talk about groundwater drought in water abundant aquifers where there is no measurable consequences on living species at very low groundwater stages compared to long-term data? Can the notion of drought be unique defined for different climatic zones, aquifer dimensions and times of groundwater retention in aquifers? Moreover, what is the influence of different aquifer boundary conditions on groundwater quantity status in areas with same climate conditions?

The first part of the research deals with comparison of three different approaches for drought index calculation with aim to determine optimal index for groundwater drought assessment. The index chosen was analogous to calculation of the standardized index of precipitation quantity where the input variable is groundwater level. World Meteorological Organization (WMO) and Global Water Partnership (GWP) (2016) also recommends the approach used.

The second part of the research is focused on comparison of the standardized groundwater index values (SGI) distribution in time and space for 12 groundwater-measuring stations of alluvial aquifers of Pomurje region in NE of Slovenia in period 1981-2016 where precipitation and surface water discharge values of the area are also taken into consideration. Temporal and spatial distribution of SGI is furthermore considered as the consequence of natural and/or anthropogenic impact. Established statistical methods used in the analyses include cluster, correlation and cross correlation methods.

Based on the results of the study conclusions are summarized as follows:
- Groundwater drought is a heterogeneous phenomenon, which can not be solely determined on the basis of the current climatic characteristics of investigated area.
- Groundwater drought can be influenced by boundary conditions apart from direct infiltration of precipitation, which are not necessarily synchronized.
- Groundwater drought usually have lag time concerning the input parameters of groundwater recharge and can last long after the input parameters that caused the drought are no longer significant.
- In addition to the intensity, the length of the groundwater drought play the important factor in drought identification.
- Anthropogenic influences, whether local or regional, have the impact on groundwater quantity status and should be considered in groundwater drought studies.

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Session Classification: Poster with refreshments

Track Classification: Topic 5 - Tools, methods and models to study groundwater
Combining unsaturated zone modelling with indirect and direct measurements to quantify solute transport during snowmelt

Monday, 23 September 2019 15:15 (15)

To improve risk assessment, monitoring, and treatment strategies of contaminated sites in cold climates, we require improved methods for monitoring solute transport and infiltration in the unsaturated zone. Previous studies have documented a highly heterogeneous infiltration during snowmelt this may have a large influence on the risk of contaminating the groundwater in areas where the use of de-icing chemicals is required for winter maintenance of roads and runways. In the last decades the use of geophysical techniques has become more widespread in order to monitor hydrogeological processes. The bulk electrical resistivity of an unsaturated soil profile is a function of soil water content, electrical conductivity of the fluid phase and soil temperature. Time-lapse electrical resistivity tomography (ERT) of a thawing partly frozen unsaturated zone during snowmelt infiltration gives a qualitative impression of how meltwater and salts moves through the unsaturated zone. Here we explore whether the ground truthing methods such as soil water samples from suction cups providing electrical conductivity of the water, tensiometer readings providing information about soil water content and soil temperature can quantify the different contributors to the change in electrical resistivity. The work is based on a combination of a field experiment during the snowmelt of 2010 and unsaturated zone modelling with Sutra_2D3D. The field experiment was conducted at Moreppen experimental lysimeter trench. Which is located next to Oslo airport, Gardermoen, Norway, where large amounts of de-icing chemicals are used to remove snow and ice every winter. During snowmelt these chemicals (Propylene glycol is used for the air planes and Potassium Formate used for the runways) infiltrate into the soil. Bromide, as an inactive tracer, and de-icing chemicals potassium formate and propylene glycol were applied to the snow cover prior to the onset of snowmelt and their percolation through the unsaturated zone was monitored with water sampling from 30 suction cups. At the same time cross-borehole electrical time-lapse measurements (with Syscal Pro, Iris instruments) and automatic measurements of soil tension and temperature were collected. Individual inversions were temperature corrected, to compensate for the change in soil temperature throughout the melting period. To estimate water contents from the ERT values, petro-physical relationships and fitting parameters from soil at Moreppen were used, this gave water contents similar to those estimated from tensiometers. Since petro-physical relationships are required to convert changes in electrical resistivity to changes in water contents and electrical conductivity of the fluid phase, experimental data was compared with a numerical model. We used the unsaturated zone model SUTRA-2D3D to explore the sensitivity of the parameters in the van Genuchten soil retention curve, and porosity, to the quantitative interpretation of the water and solute behaviour based on the time-lapse electrical resistivity measurements.
Session Classification: Parallel

Track Classification: Topic 5.3 - Advanced modelling tools for subsurface hydrology: from the vadose zone to deep environments
Flow path and velocity by 3-D groundwater flow simulation based on detailed facies analysis of Fukushima Daiichi Nuclear Power Station in Japan

Since 2011, groundwater contaminated by radionuclides from Fukushima Daiichi Nuclear Power Station (FDNPS) in Japan, flows into the adjacent sea. Despite several countermeasures to prevent outflow of contaminated groundwater into the sea, this issue has not been solved. Contaminated groundwater primarily flows through the unconsolidated sand layer of the upper Pliocene (the Dainenji Formation), which the nuclear reactor was built in. However, results of field survey in areas surrounding FDNPS and boring logs analysis, show that the sand layer is not distributed uniformly and has irregular intercalations of several muddy layers. Such results are needed to reveal heterogeneous facies considering flow path and velocity of contaminated groundwater. In this study, 3-D groundwater flow simulation based on detailed facies to reproduce heterogeneity in the formation was carried out using MODFLOW. Groundwater flow was analyzed by transient simulation. Flow path and velocity of groundwater through the sand layer were controlled by non-uniformly distributed muddy layers. Land and sea side impermeable walls which are countermeasures at FDNPS, reduced outflow of groundwater through the unconsolidated sand layer to the sea. Assuming the impermeable walls do not exist on the simulation model, groundwater outflow to the sea is within the harbor. Potential upward groundwater flow appeared under reactor and turbine buildings. Groundwater flows from a lower aquifer to the upper aquifer through the sandy mud layers below these buildings. In the next step, mass transport simulation of contaminated groundwater will be performed based on results of groundwater flow simulation.

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Session Classification : Parallel

Track Classification : Topic 8 - Groundwater quality and pollution processes
Isotope studies and other hydrogeological techniques to estimate groundwater contributions to a swamp ecosystem

Thursday, 26 September 2019 11:30 (15)

The Temperate highland peat swamps on sandstone (THPSS) in Eastern Australia are a threatened ecological community with endemic flora and fauna. The ecological health of the THPSS swamps are sensitive to changing swamp moisture content and saturation. There are multiple risks to many of these swamps from variable climate, wild fire, recreational vehicles and underground mining. At Newnes Plateau, some swamps are located above and near longwall coal mines that operate at a depth of several hundred metres below ground surface. Here we highlight findings of a recent study of pore water stable isotopes within selected swamps, and new groundwater monitoring data that is publically available.

We used stable isotopes to evaluate groundwater contribution to three selected swamps (CC, GG, and GGSW) under different rainfall conditions, including analysis of pore water within swamp sediments using a direct vapour equilibration method. The October 2016 (cool weather) samples from CC swamp were typically depleted in δ18O and δ2H and we concluded that these values were within the range of winter rainfall isotope values. The isotope signature in the partially saturated zone in the warm period (May 2016) was a result of evaporation. Below 100 cm depth the values of δ18O remained uniform and consistent with groundwater values but also with surface water. The isotope results enabled key hydrological processes to be identified including rapid infiltration of rainfall to the water table and lateral groundwater flow at the base of the swamps. The method also enabled improved accuracy in quantification of evapotranspiration. It was found between 2016 and May 2017 that groundwater contribution to the swamps was significant.

Groundwater levels near one of the swamps in this study (swamp GG) were subsequently affected by underground mining. At monitoring site SPR1104, installed in a sandstone aquifer on the ridge above the swamp, groundwater levels dropped rapidly below the base of the piezometer in July 2017. This drawdown occurred immediately after mining longwall 420 directly below the monitoring site and is attributed to bed separation effects and changes in sub-surface storage. However, some drawdown was also observed due to an earlier longwall mining through a fault structure that was at least ~600 m distant. Hydrological changes within the swamp that have occurred during this period are yet to be fully evaluated.

Further work is required to quantify the importance of groundwater flow to the swamps from different sandstone aquifers below and above the swamps, particularly given natural variations between wet and dry periods. It is important to quantify complex changes to the hydrology of swamp ecosystems over the long term at both reference and mining impacted swamps.

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Session Classification : Parallel

Track Classification : Topic 6 - Groundwater, wetlands and natural heritage
MAPPING OF SUITABLE ZONES FOR MANUAL DRILLING IN RDC AND SETTING UP A NATIONAL GROUNDWATER DATABASE

Monday, 23 September 2019 17:15 (15)

Introduction
Despite continued efforts, in the Democratic Republic of Congo (DRC) only 52% of its population having access to a water point in 2015, and even less in rural areas. To find low-cost solutions, UNICEF has implemented in 2012 a programme in order to professionalize the manual drilling sector. But an effective strategy for development of manual drilling requires the identification of areas with favourable hydrogeological conditions.

Methodology
The methodology used in this work derives from UNICEF experience in 16 other African countries and a research project in Guinea Conakry and Senegal managed by the University Milano Bicocca. It is based on the integration of existing data, together with field experiences of local technicians.

The aptitude to manual drilling derives from the combination of:

1. The feasibility: possibility of drilling using manual techniques and of reaching an aquifer. It has been estimated from the depth of rock and the depth of water
2. The potential for exploitation: semi-quantitative assessment of potential yield estimated indirectly from the thickness of coarse layers in the exploitable aquifer
3. The presence of partially hard layers that increase time and cost for drilling

The procedure for the estimation of the aptitude for manual drilling at national level has been carried out through these steps: 1) collection of available data and stratigraphic logs; 2) organization and standardization of data in a specifically designed database; 3) estimation of hardness and permeability for regular intervals of 1 m, using a semiautomatic method; 4) extraction of a set of hydrogeological parameters; 5) estimation of the class of feasibility, potential and difficulty of perforation for each drill; 6) extrapolation of feasibility and potential to the whole country on the basis of geological map and morphology; 7) comparison with the direct expertise of drillers and water technicians.

Results
The majority of the territory is located in areas favourable to manual drilling (42% classified with high or very high aptitude, 24% moderate), especially in the western part of the country, covered by thick loose layers. On the other hand, in the east of the country there is a strong presence of crystalline rocks that form favourable discontinuous alteration layers. One of the main contributions of this project is the creation of a database at a national level in which the information used and generated is collected and organized.

Conclusions
Manual drilling currently exists in several areas of the country, but is also non-existent in some provinces despite their favourable or moderately favourable conditions for manual drilling. The dissemination of this technique can improve the access to water.

Indeed, the database is designed as a dynamic tool that, regularly updated, is an important support for groundwater resource management.
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Session Classification : Parallel

Track Classification : Topic 3.1 - Groundwater and water security in developing countries
GEOMORPHOLOGICAL CHARACTERISTICS OF THE FLASH FLOOD AFFETED AREA DURING CEMPAKA TROPICAL CYCLONE IN GUNUNGSEWU KARST AREA, INDONESIA

Monday, 23 September 2019 15:30 (15)

Cempaka tropical Cyclone occurred on 27 November 2017 in the Indian Ocean, just south of Central Java. The cyclone generated an extrem rainfall and flash floods in Southern part of Central Java, including the Gunungsewu Karst Area. The highest rainfall recorded on November 28, 2017 in area is 369 mm/day. This study aimed at analyzing the geomorphological characteristics of affected areas. The analysis was conducted by mapping the flooded sites, morphological analysis, and morphometry analysis using a topographical map, high-resolution remote sensing image and high-resolution image from unmanned aerial vehicle (UAV). The results show that floods in the study site occurred in (1) flash swallet hole, (2) karst window, (3) resurgence and (4) flash flood in doline with small ponor.

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Session Classification: Parallel

Track Classification: Topic 2 - Groundwater and climate change
Groundwater Management and Governance: Science is Necessary but Insufficient

Tuesday, 24 September 2019 11:45 (15)

As long as humans have existed on planet Earth groundwater has been inextricably linked with people and the world we live in. It is front and centre in critical contemporary issues about our environment, food and water security, coal seam gas and fracking, mining, energy and nuclear waste disposal. Groundwater supplies half of the world’s drinking water and nearly half of the water used for growing food. Groundwater depletion and pollution are major global problems. In its Global Risks 2015 Report, the World Economic Forum ranks water crises as the number one risk in terms of impact to society – ahead of weapons of mass destruction, spread of infectious disease, failure of climate change adaptation and fiscal crises. Climate change and population growth will place additional stress on already stretched groundwater resources.

Groundwater management and governance are vital for humans and humanity. Groundwater is a divisive, contentious, controversial and emotive issue. Tensions between farmers, mining companies, and the environment are at an all-time high. The community is alarmed by fracking in shale gas production and the possibility it could contaminate groundwater. Managing groundwater – scientifically, environmentally, economically and socially – is a grand challenge.

Humans are fundamentally social animals. We often hear about a social license to operate for mining or even a social license for a new government policy. But what does that really mean and what does it take to gain such a license? We, as scientists, often think and act as if science is enough and that having ‘found’ a solution it is someone else’s problem to ‘make it happen’. However, science is necessary but insufficient for effective, socially acceptable groundwater management and governance. There are extraordinary political, psychosocial and socioeconomic factors at play that must be understood. There is public misinformation and disinformation, understanding and misunderstanding, interest and disinterest, unconscious bias, emotion, perceptions and the like. There are critical, complex and complicated social, economic and environmental drivers and interests. We ignore these at our peril. Groundwater is a science. Groundwater is also fundamentally and crucially a social science. This talk explores critical psychosocial factors that underpin groundwater and its role in humanity and the future of our planet.

Recent global events have proven that science alone is not enough. The success of future groundwater management and governance hinges critically upon both scientific knowledge and social sensibility. These are enormous challenges and opportunities for groundwater; but we must rise to these challenges. We owe it to current and future generations; and our profession.

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Session Classification : Parallel

Track Classification : Topic 3 - Groundwater sustainability and governance
Assessment of groundwater contamination vulnerability in a predominant fractured rock-aquifer area

Monday, 23 September 2019 16:00 (60)

This study was carried out in the Miryang City, Korea where had the characteristics of urban and rural functions. The study area is surrounded by high mountains except the southern part which forms the flat area around the large Nakdong River. The city area is about 800km² and about 5,200 wells are developed there. 325 wells were investigated for the sustainable development and effective management. 230 wells located in the fractured rock, and 95 wells were in the unconsolidated deposits such as alluvium, colluvium and highly to completely weathered rock. Advanced DRASIC Model (ADM) adding 2 more factors of land use and lineament density to Original DRASIC Model (ODM) of 7 factors were applied for the assessment of groundwater contamination vulnerability in the study area. In case of all monitoring wells, ADM produced a more accurate contamination vulnerability map and a larger correlation coefficient between contamination vulnerability index and NO3-N concentration comparing to ODM. The correlation coefficients of ADM and ODM were 0.35 and 0.24, respectively. In two cases of all monitoring wells and unconsolidated aquifer wells, ADM of unconsolidated aquifer wells produced a more reasonable contamination vulnerability map and a larger correlation coefficient between contamination vulnerability index and NO3-N concentration, comparing to ADM of all monitoring wells. The correlation coefficients of all monitoring wells and unconsolidated aquifer wells were 0.35 and 0.74, respectively. Thus, the assessment of groundwater contamination vulnerability was more effective for the unconsolidated aquifer than the whole aquifer of unconsolidated material and rock because DRASIC evaluation basically assumed that groundwater contamination was conducted through the surface ground. Artificial Neural Networks (ANN) technique was also applied for the vulnerability assessment of unconsolidated aquifer. ANN model (ANNM) rendered a more accurate contamination vulnerability map and a larger correlation coefficient between contamination vulnerability index and NO3-N concentration, when compared to the application of simple ODM. The correlation coefficients of ANNM and ODM were 0.81 and 0.74, respectively. It was concluded that the assessment of groundwater contamination vulnerability in a predominant fractured rock-aquifer could draw the better result in conducting the evaluation only of the unconsolidated aquifer except the fractured rock aquifer, and that ANNM was very effective for the evaluation of groundwater contamination vulnerability.
Exploring the use of Fiber Optic Distributed Temperature Sensing for monitoring seawater intrusion

Monday, 23 September 2019 15:45 (15)

As pressure on coastal fresh groundwater resources increases, interest in coastal aquifers monitoring rises. The weakest point of coastal aquifers occurs at the fresh-salt water interface induced by seawater intrusion (SWI), highly sensible to any change in the heads of the fresh and salt water bodies. Therefore, the position, width and dynamics of the interface is one of the main features of a coastal aquifer to be monitored and understood, in order to improve coastal groundwater management.

Traditionally, changes in electric conductivity have been used to identify and monitor the interface in coastal aquifers. Alternatively, natural differences in temperature between fresh and the saline groundwater bodies are also known to provide useful information. Recently, Fibre Optic Distributed Temperature Sensing (FO-DTS) is increasingly being used in the field of hydrogeology because of its high spatial and temporal resolution. To test the FO-DTS technology for the monitoring and quantification of the SWI dynamics, distributed temperature data were collected every 15 minutes in a Mediterranean granular aquifer, matching with the occurrence of an extreme rainfall event. Thermal response to the recharge event is compared to data collected independently in wells with electrical conductivity and temperature probes. A 2D variable density heat and solutes transport model is performed with CodeBright. The numerical model is used to confirm the conceptual model defined from the interpretation of the FO-DTS data, explore possible future scenarios and prove the usability of this technology for coastal aquifers monitoring.

Distributed temperature data reflect thermal responses to the extreme recharge event. However, smaller displacement of the interface, like those produced by tides, were not detected by FO-DTS. Only hydraulic processes with thermal responses larger than 0.15 °C could be observed with this technology. Therefore, the high spatial and temporal resolution provided by FO-DTS is limited by its temperature resolution, which depends on many factors, such as the DTS sensor, the number of connections, the calibration baths and the calibration process. In any case, it is a promising technology for monitoring fast responses of the interface to large scale processes like recharge events.

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**Session Classification:** Parallel

**Track Classification:** Topic 5 - Tools, methods and models to study groundwater
INCORPORATING THE SPATIAL VARIABILITY OF TRITIUM IN PRECIPITATION TO CONSTRAIN THE DISTRIBUTION OF GROUNDWATER TRITIUM AND MODERN RECHARGE IN SOUTH AFRICA

Friday, 27 September 2019 12:15 (15)

Tritium, the radioactive isotope of hydrogen, has been used to understand groundwater recharge processes for decades. The versatility of tritium as an isotopic tracer of recharge was most pronounced during the tritium “bomb peak” in the late 1960’s and 70’s, when the tritium activity in the atmosphere was several orders of magnitude higher than natural background levels. Since then, the activity of tritium in the atmosphere has decayed back to background levels, particularly in the southern hemisphere. Thus, the current variation of tritium in the atmosphere can be largely attributed to regional stratospheric production and fall out rates as well as global circulation phenomena. Unfortunately, more local controls on the variability in atmospheric tritium activity are poorly constrained and tritium activities in precipitation are often assumed to be uniform over both local and regional catchments and watersheds. This assumption can result in both over and under estimation of modern recharge within an aquifer when using tritium as the recharge proxy. In order to minimize the inherent prediction residuals associated with tritium based recharge investigations within a specific catchment, the variability of tritium activity in rainfall across that catchment must be better constrained. The variability of tritium in rainfall was modelled from 142 spatially distinct rainwater samples taken over a two year period, combined with a 77 rainwater sample group-set taken over a one year period in a single location. Rainfall events are traced backward in time, from the point of collection, using HYSPLIT modelling to ascertain the origins of moisture as well as the maximum altitudes reached along the particle track. It is evident that particles originating from lower latitudes, as well as those reaching higher altitudes, have generally elevated tritium signals. The variability of tritium, both spatially and temporally, was significantly higher than expected, confirming that assuming uniform tritium inputs to the groundwater system would result in inaccurate modern recharge estimates. Higher spatial resolution of tritium variation in rainfall for a particular region will improve our ability to relate tritium activities in groundwater to local precipitation. The distribution of tritium in groundwater alone cannot characterize the extent of modern recharge in areas where rainfall has anomalously variable tritium activities. It is evident that regions receiving both convective and stratiform rainfall, which originates from contrasting latitudes and altitudes, have elevated variability in tritium. The characterization of local variability of tritium activities in rainfall/recharge must now become an important step when investigating modern recharge using tritium as an isotopic tracer.

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Session Classification : Parallel
Track Classification: Topic 5 - Tools, methods and models to study groundwater
Effect of microbially mediated sulfate reduction on arsenic mobilization in the Pleistocene aquifers of the central Yangtze River Basin

Monday, 23 September 2019 17:30 (15)

Understanding the mechanism of geogenic arsenic mobilization from sediments to groundwater is important for safe and sustainable drinking water supply and water quality management in floodplain aquifers. Laboratory-scale microcosm incubation experiments and seasonal biogeochemical monitoring were conducted to elaborate the effects of microbial sulfate reduction on As mobilization in the shallow aquifer systems from the Jianghan Plain, central Yangtze River Basin. Dissolved As species (including thio-As), Fe(II), dsrB/arrA functional gene abundance, 16S rRNA gene sequences and iron mineral phase transformation (by sequential extraction) were analyzed during the incubation and field monitoring study.

Sulfate reduction promoted arsenic mobilization at the initial stage of microcosm incubation with the increase of dsrB gene and arrA gene abundance, since sulfidogenesis significantly contributed to the mobilization of As via sulfide-induced reduction of both As-bearing Fe(III) oxide minerals and As(V), while a part of the arsenic was converted to soluble thio-arsenates (H2AsS4-). 16S rRNA gene sequences identified as Desulfomicrobium could be responsible for the microbially mediated sulfate reduction process. A decrease of dissolved As and Fe(II) was observed at 14th day after incubation, the results of sequential extraction of sediments indicated the increase of Fe(II) sulfide mineral phases, suggesting the precipitation of Fe(II) sulfides can restrict the build-up of dissolved Fe(II) and sequester As from the solution. Then after transient arsenic removal, As re-released into the solution without corresponding increase of dissolved Fe(II), probably due to the competitive adsorption for the surface sites of iron-sulfide minerals between As and other ions (Fe(II), bicarbonate, etc.) and newly formed crystalline iron (hydro)oxides.

Our lab-scale microcosm observation was consistent with the results from our long-term field monitoring. Microbially mediated sulfate reduction could promote seasonal increase of As and Fe(II) through abiotic reduction of iron (hydro)oxides minerals in aquifer sediments by bacterially generated HS-, which was evidenced by corresponding increase between Fe(II) and δ34SSO4 in groundwater. Moreover, Fe(II) sulfide formation could scavenge the dissolved Fe(II), which leads to the decoupled seasonal variation of As and Fe(II) under sulfidogenesis conditions. While sulfate reduction process only resulted in transient and incomplete arsenic immobilization due to competitive adsorption between As and phosphate in groundwater. Our results provide new insights into the coupled As-Fe-S biogeochemical processes accounting for arsenic mobilization and seasonal variation in alluvial aquifer systems.

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**Session Classification**: Parallel

**Track Classification**: Topic 8 - Groundwater quality and pollution processes
Advances in understanding long-tailed breakthrough curves from tracer tests in karst aquifers

Thursday, 26 September 2019 15:00 (15)

Karst aquifers are important drinking water resources. However, they are highly vulnerable to contamination. Contaminants can be transported rapidly through the network of conduits or fractures with only limited sorption or degradation. This leads to a fast and strong response at the karst springs and, along with it, a rapid decrease in the water quality. In addition to this, contaminants can also enter immobile zones, such as pools and riffles, or move into the adjacent fractured rock matrix. As the concentrations in the main flowpath decrease, contaminants may migrate back into the main flowpath and reach the karst springs at lower concentrations, but for a longer time-span. This is the conventional interpretation for the steep rising limb and the long-tailed falling limb of tracer breakthrough curves which are often-observed phenomena in karst systems. Such behavior cannot be quantified by the conventional advection-dispersion equation (ADE). The two-region, non-equilibrium model (2RNE), which includes mobile and immobile zones, delivers a relatively good approximation of the breakthrough curves. However, in most cases, even the 2RNE fails to simulate the lowermost concentrations at the longest travel times. In this context, the continuous time random walk (CTRW) approach can be applied to understand such long-tailed breakthrough curves. CTRW accounts for the anomalous (or non-Fickian) transport behavior which characterizes heterogeneous systems, such as karst.

We examined examples from an alpine karst system in Austria where we observed distinctive long-tailed breakthrough curves of the conservative tracers. We present several modeling approaches – (i) ADE, (ii) 2RNE and (iii) CTRW – and show that CTRW describes the observed tracer behavior. The CTRW approach is a physically-based framework that accounts for the various transport mechanisms, and simulates even the late and low concentrations.

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Session Classification : Parallel
Track Classification : Topic 7 - Karst Hydrogeology
Dealing with seawater intrusion in the Chtouka Aquifer, Morocco

Monday, 23 September 2019 15:45 (15)

The joint technical cooperation project CREM (Coopération régionale pour une Gestion Durable des Ressources en Eau au Maghreb) of OSS (Observatoire du Sahara et du Sahel), BGR (Federal Institute for Geosciences and Natural Resources), and GIZ (German Society for International Cooperation) is funded by BMZ (German Federal Ministry for Economic Cooperation and Development) and fosters the exchange of groundwater management strategies between the three countries Morocco, Algeria, and Tunisia. The strategic focus in the pilot area of Souss-Massa, Morocco, by BGR is on saltwater intrusion.

The Souss-Massa Basin is the country’s most important agricultural area. Groundwater from the coastal Chtouka aquifer is the main source for irrigation. The heavy exploitation of groundwater leads to declining water level in the sub-basin, with the effect of intruding seawater from the ocean. Several measurement campaigns were launched together with the ABHSM (Agence de Bassins Hydrauliques Souss-Massa) and the University of Agadir. Wells and monitoring boreholes along the coast were visited, altitudes and water level data were gathered, and depth specific electrical conductivity profiles were taken.

Results show an average groundwater depletion of up to 1.5 m per year in several locations. Due to this depletion, a change of the general flow direction in the Chtouka Aquifer was found. The mobilisation of high saline water from the south of the plain and the marine intrusion threaten the irrigated zones. The hydrochemical analyses identified a zone of wells with marine influence. Additional monitoring wells were drilled. A three dimensional density dependent numerical model is used to simulate groundwater flow and the development of salinities in the Chtouka aquifer.

Countermeasures are already in progress, e.g. the construction of a water desalination plant for agricultural purposes and a so-called aquifer contract. In international workshops, the project’s results, as well as strategies are discussed with the aim to transfer the achievements to other OSS member countries, i.e. Tunisia and Algeria.

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Session Classification : Parallel

Track Classification : Topic 1 - Groundwater assessment and management
Limitations of current protocols to predict groundwater contamination from alkaline mine waste

The leachates generated by mining wastes have been widely studied, regulated and identified as the main environmental concern for both groundwater and surface water pollution (e.g. Ochieng et al., 2010). However, only acid leachates are considered environmentally harmful, while neutral and alkaline mine drainage (NAMD) is mostly conceived as harmless effluent. Recent studies are showcasing that alkaline leachates can be toxic to humans and the environment (Gomes et al., 2016). But nowadays, there is poor regulation and international consensus about how to proceed when mine wastes produce NAMD.

In order to demonstrate the limitations of current regulations and protocols, the present study compares the results of different leaching tests performed to waste rock dump (WRD) and tailing samples from Phalaborwa Industrial Complex (South Africa), with the characteristics of the groundwater underneath of them.

14 sample were analysed by acid rock drainage classification tests (ARD-CT) such as paste pH-EC, Static Net Acid Generation (NAG), Acid Base Accounting (ABA) and textural Acid Rock Drainage Index (ARDI). Despite some discrepancies with a feldspathic pyroxenite sample (according to NAG, it would fall under the classification of Potential Acid Forming-Low Capacity), the rest of the samples were classified as non-acid producing or even acid consuming. Consequently, no further analysis was required for them, according to protocols (e.g. Usher et al., 2003).

Complementary tests were conducted to assess their potential toxicity, bioavailability and mobility of trace metals. The results from the Toxic Characteristic Leaching Procedure (TCLP) showed that all the samples are bellow toxicity thresholds (US EPA, 1998). Whereas Leachable Concentration Tests (LCT) and sequential extraction (bioavailable (F1) + reducible (F2)) exceeded the South African limits for inert waste classification on all the tailing samples and 60% of the WRD samples. In addition, when LCT was correlated with TCT, as described in GNR 635 (2013), all the samples were classified as waste type 3 non-harmful. In contrast, the analysis of groundwater samples showed TDS up to 8200 mg/L (2697 mg/L, on average); sulphate up to 6040 mg/L (1267 mg/L, on average); and Cl up to 1465 mg/L (329.8 mg/L, on average). In fact, these results correspond with high salts concentration (Ca, Na, Mg, sulphate, fluoride and chlorides) detected during the analyses of the leachates. Due to the high salinity, the groundwater is not suitable for farm stock, irrigation nor drinking water (SANS 241:2011).

While specific mine waste characterizations (ARD-CT) are based on leachates’ acidity, thresholds for waste landfill classification are focused on toxic trace metals (more likely to be released under acidic conditions). There are no tests nor thresholds established that targets saline leachates prediction and its adverse impact on groundwater.

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**Session Classification:** Parallel

**Track Classification:** Topic 8 - Groundwater quality and pollution processes
Source identification of groundwater nitrate in an agro-livestock farming area, western part of Jeju Island, Korea: The combined use of multivariate statistical analysis and Bayesian mixing model to hydrochemical and nitrate dual isotopic data

Thursday, 26 September 2019 16:00 (60)

Groundwater is the unique source of water supply in Jeju Island, South Korea, which was formed by multiple eruptions of basaltic to trachytic volcanic rocks during Quaternary. Recently, there has been a significant concern on nitrate contamination of groundwater in the Hanlim area at the northwestern part of Jeju Island. In order to determine the contribution of diverse sources to the observed nitrate contamination, we collected a total of 172 groundwater samples from 49 preexisting wells and the samples were analyzed for hydrochemical and nitrate N-O isotopic data. In the study area, agricultural fields account for 44% of the total area and mostly occupy topographically low lands (~ 250 m asl), while livestock farms and pastures are scattered at elevations between about 100 and 350 m asl. Intensive livestock (mostly, pig) farming is prevailing around a small pyroclastic cone (named Kum Oreum) near the altitude of about 300 m. The 10th to 90th range of observed NO3 concentrations was 5.8 to 80.5 mg/L, and groundwater samples from 13 wells exceeded Korean drinking water standard (44.3 mg/L NO3). The hydrochemistry of groundwater in the study area gradually changed from Na-HCO3 type to Ca-Mg-Cl type with the concomitant increase of NO3 concentrations. The Principal component analysis (PCA) of hydrochemical data showed that the effects of livestock farming and agricultural activities on groundwater quality are coexisting with those of natural water-rock interaction. The dual N-O isotopic compositions of nitrate indicated that manure-derived contamination is characteristic in the study area. The long-term illegal dumping of manure slurry from intensified livestock farms into the zone of permeable volcanic clinkers likely resulted in the contamination of groundwater by nitrate characteristically with extremely high δ15N values. The results of the application of Bayesian mixing model (SIAR) to determine the proportions of two important nitrate sources (i.e., chemical fertilizers and manure slurry) showed that nitrate contamination from manure slurry occurs preferentially along the direction of lava caves beneath the intensified pig farming area, while nitrate from chemical fertilizers is dominant beneath agricultural areas. Even so, deep aquifers that are used for liquor production in the coastal area are free of nitrate contamination. This study suggests that in order to manage groundwater under the complex geologic setting with multi-layered volcanic strata, a better understanding of subsurface geology is crucial.

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**Session Classification:** Poster with refreshments

**Track Classification:** Topic 8 - Groundwater quality and pollution processes
Application of the climatic water balance method for recharge evaluation and extreme climate indices analysis in the northern region of Rio de Janeiro state - BR at the present climate

Monday, 23 September 2019 16:00 (60)

The increasing use of groundwater as an alternative source to meet the water demand leads to the necessity of availability studies and the influence of climate variations to aquifer recharge. Assessment of aquifer behavior in face of climate change scenarios may provide invaluable information and can assist in the planning and management of these resources. The objective of this work is to use climate data (precipitation and temperature) to estimate recharge using Thornthwaite-Mather (1955) method through simulations with groundwater budget software and extreme climate indices analysis using the software RClimDex elaborated by the Meteorological Service of Canada.

The climatological analysis of Campos dos Goytacazes municipality, located in the northern region of Rio de Janeiro state - Brazil to the period of 1961-1990 indicates an annual rainfall relatively low (1055 mm) with 64% of the total (672 mm) concentrated in the rainy period that goes from October to January. The number of rainy days (days which total rainfall exceeds 1 mm) fluctuates between 4 and 12 in June and December, respectively. With respect to consecutive dry days, the average is around 30 and 35 days/year, which probably occurs in the winter period. The compensated temperature oscillates between 20.7 °C in July and 26.6 °C in February.

The recharge estimate was elaborated through the Hydrometeorological Balance using temperature and precipitation data obtained from the meteorological station of the Brazilian Institute of Meteorology (INMET) located in the city of Campos dos Goytacazes - RJ for the period of 1961/01/01 to 2016/12/31 using as tool the software Easybal 4.0 (Vazquéz-Suñe and Castro, 2002), provided average annual precipitation results of 958.2 mm and average annual recharge of 232.32 mm, so approximately 22% of the water that precipitates in the form of rain percolates and arrives at the aquifer recharging it. The obtained results show a high correlation (0.93) between the recharge and precipitation values in the study area, so that the precipitation variations are directly related to the variations of the recharge to the aquifer.

Results also indicate an increase trend in temperature and a decrease in rainfall in the study area, which is becoming hotter and dryer through time. As rainfall and recharge trends are strong related, it is possible to conclude that a decrease in rainfall leads to a decrease in the recharge. This process is certainly accelerated by climate change and affects the water availability in the aquifer, reducing its water potential.

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Session Classification: Poster with refreshments
Track Classification: Topic 2 - Groundwater and climate change
Integral water management, a challenge in the Pacific Slope of Guatemala, C.A.

Friday, 27 September 2019 09:55 (15)

The Pacific slope of Guatemala stretches from the Guatemalan volcanic belt to the Pacific littoral, covering over 25% of the country. Due to its flat landform, to the type of sediments and to its climatic characteristics, the intensive agriculture has develop during the last decades. Nowadays, most of the area is devoted to agriculture. Next to the volcanic chain, coffee plantations and basic grains as corn and beans predominate, while in the medium part the majority of crops are dense forest of rubber and part of the sugar plantations. Finally, in the most littoral part are located the biggest part of the sugar production, next to the oil palms and bananas farms. So far, the water needed for the irrigation of these crops was provided by the surface streams in the area, that are characterized by a high flow rate due to high precipitations especially during the rainy season. But the reliability of the superficial water demonstrated its limitations between the years 2015 and 2017, when one of the biggest El Niño events ever registered occurred. This situation caused severe drought conditions in Guatemala Pacific basin in the following year. The rate flow of the principal streams went down and they mostly dried up. On the other hand, the superficial wells also dried up and the local population who depends on these resources for their consummation was affected. A conflict started between local inhabitants and the agro-industry. Finally, the water scarcity situation was managed successfully by the formation of water users boards and surface water monitoring systems, leaded by the Private Institute for Climate Change Research (ICC). But in this scarcity scenario groundwater has been found to be an alternative for water supply. Today, the number of groundwater extractions increase dramatically, without any management. The hydrogeological information and studies in this area of the country are really scarce, and there’s no national governance of water resources. The uncontrolled extractions of groundwater could lead to serious consequences, as the diminution of the groundwater resources of the local population and the decrease of the water levels in rivers and ecosystems associated. In order to impulse the management of groundwater, ICC started the investigations in hydrogeology since 2015, as a part of one of its research programs. A first groundwater flow characterization has been carried out, including geochemical and isotopic studies, and periodic measurement of groundwater levels in the wells of the area. During the next five years, ICC pretends to enhance the investigations in groundwater in the area, to start an integral management of the water resources and to permit a sustainable exploitation.

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Session Classification: Parallel

Track Classification: Topic 9 - Groundwater and socio-economic development in Latin-America
Biogeochemical precipitates at the terminal points of regional groundwater flow systems as analogs for geothermal plants and past processes

As regional groundwater flow systems arise to the surface as a reductive thermal spring with high TDS, CO2 and often also high trace element and 226Ra content, complex biogeochemical processes begin. Buda Thermal Karst system (Hungary) is a regional discharge area, where these processes can be studied near the surface. The surface of carbonate rocks where the reductive thermal water and the oxidative air interacts (redox environment change), provide a good inhabitation for biofilm-forming bacteria. Escaping CO2 increases the water’s saturation with respect to calcite, resulting in calcite precipitation. These two major driving forces lead to the formation of biogeochemical precipitates (BGP). BGP have a high absorption capacity, accumulating large amount of trace elements and radionuclides from the water. The simultaneous examination of the parent fluid and the forming precipitates with comprehensive analytical methods, such as scanning electron microscopy, stereo microscopy, X-ray powder diffraction, inductively coupled plasma mass spectrometry, gamma spectroscopy, give a chance to better understand the ongoing processes. The results of the nature-based experiences were used in the analysis of scales, formed in geothermal plants, as the same processes act also in man-made systems. Furthermore, we could use the purchased information during the comparison of recent and paleo spring cave precipitates of the Buda Thermal Karst, to find indicators for similar paleo processes.

This study is part of a project that has received funding from the European Union’s Horizon 2020 research and innovation programme under grant agreement No 810980.
Human impact on groundwater resources in a context of hot semi-arid climate and intensive exploitation – Case of the Haouz aquifer (Morocco)

The monitoring (piezometric control) of the shallow aquifer in Marrakech and its area shows that the water-table lowered gradually during the 40 last years, with a strong accelerated decline (massive drop) in the water level from the early 2000s. This declining trend -if confirmed in the future- may lead to a water shortage, or even total aquifer depletion, which would be devastating for a region where economic activity and drinking water supply is partly based on groundwater resources.

Two factors account for this situation:
- The hot semi-arid climate of the region characterized by high temperatures and low precipitations. This is causing an inadequate groundwater recharge (deficit between rainwater supply and the potential evapotranspiration).
- The over-pumping of groundwater from wells for intensive agricultural uses and some leisure activity (golfs, waterparks and pools for example).

The objective of this study is to assess the impact of human activity on groundwater availability in this context of semi-arid climate and intense use conditions.

Based on earlier research studies and hydrological data recently collected from the field, a spatiotemporal analysis using a geographic information system has been conducted allowing to monitor the evolution of groundwater resources under the impact of intense uses. The areas most affected by the drawdown of the water-table have been highlighted.

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Session Classification : Parallel

Track Classification : Topic 2 - Groundwater and climate change
On Fluorescent Dye Tracing in Engineered Bio-Remediation: Insights from one year of data acquisition

Engineered bio-remediation is a promising, cost- and energy-saving, in-situ method for the treatment of soils contaminated with volatile organic compounds. In a pilot project, a combination of pump and treat and engineered bio-remediation is evaluated for the remediation of chlorinated hydrocarbons. In order to speed up the remedial work, the microbial activity is stimulated by raising the groundwater temperature to 30℃ and by phased injection of an organic substrate, while the water from the recovery wells is treated before reinjection. The groundwater is routinely sampled to monitor the distribution of the substrate, the microbial activity, and the development of the contaminant concentration.

In order to reduce the amount of manual sampling, the potential of fluorescent dye tracers as surrogates for monitoring the organic substrate distribution was evaluated. The fluorescent dye Eosin Y was mixed with the substrate solution before the injection, and its distribution was monitored for a period of one year: periodically, by weekly sampling at up to 16 observation wells, and continuously, by using a prototyped, in-line, fiber-optic fluorescence sensor connected to four of the observation wells. The obtained data shows a correlation between the development of the dye concentration and the substrate concentration. Furthermore, decomposition of Eosin Y to an Uranine like fluorescing substance was observed.

This presentation aims to elaborate on the data obtained during the long-term field experiment on tracing engineered bio-remediation: firstly, how automated, in-line fluorescence sensing can improve the management of contaminated site treatment, and secondly, the prospects of dye decomposition as an additional process parameter in engineered bio-remediation.

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Session Classification : Parallel

Track Classification : Topic 8 - Groundwater quality and pollution processes
Development of an integrated groundwater information system and its application to the Geum river basin, Korea

Monday, 23 September 2019 16:00 (60)

An integrated groundwater information system, which is a web-based platform, was developed to utilize and manage groundwater efficiently in Korea. The system was designed to input and modify data interactively by various users such as managers, well developers, and scientists. Groundwater database is coupled with a web-based modeling tool based on Analytic Element Method (AEM) (Visual AEM by James R. Craig in University of Waterloo) to assess groundwater resource and impacts from various factors such as climate change, hydrologic environment changes, and contaminant loading. The groundwater database contain the well locations and the related facilities, hydrogeological units and characteristics, geothermal data, water quality, various geo-spatial data including land use, soil type, geology etc. The groundwater modeling can be possible on the platform straightforward due to the information access in the same time. There’s a limit to what you can implement using the adopted AEM model, but it is powerful in that it can well reflect the characteristics of a large scale area flow system. The integrated system is called as GEE system, and it means Groundwater-(Geothermal) Energy-Ecosystem, which is the three components that make up the Groundwater Dependent Ecosystem (GDE). Through the development of the system, we intend to secure sustainable groundwater-geothermal resources and to maintain GDE according to climate change. Database were constructed for each of the three factors (groundwater, geothermal, ecosystem) as the components of the GEE system in the Geum river basin which is one of 4 largest basins. Furthermore, the database and groundwater modeling module on the platform in the Geum-river basin was tested and has been confirmed to be effective for a good groundwater management tool.

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Session Classification : Poster with refreshments

Track Classification : Topic 1 - Groundwater assessment and management
Rapid karst development in salt layers during and following flash floods along the shores of the Dead Sea

Thursday, 26 September 2019 11:30 (15)

The Dead Sea is a hypersaline terminal lake, located within a pull apart basin along the Dead Sea Transform. The lake’s surface water is the lowest on Earth. As such, it forms a regional drainage basin for both surface and underground water systems. At around 11,000 BP Lake Lisan, the precursor of the Dead Sea, underwent a dramatic water level decline accompanied by the precipitation of a 10-30 m halite layer. This layer was since covered by clastic sediments, and as long as it was in contact with the halite-saturated Dead Sea brine it remained intact. However, over the last few decades the Dead Sea experiences a dramatic water level decline, leading to its shrinkage and to the exposure of large mudflats, mostly along its western shores, where the bathymetry is moderate. Concurrently, the water level in the adjacent coastal aquifer drops, and the halite-saturated brine in the subsurface is being flushed towards the receding lake by less saline groundwater. As these halite-undersaturated waters encounter the salt layer, it initiates dissolution, creating underground cavities, which consequently collapse to form thousands of sinkholes along the retreating shore.

Over the past few years it became apparent that besides the sinkholes that puncture the surface, a highly developed karst-like system connected to the surface rapidly develops within the salt layer, mostly adjacent to the gullies that drain surface runoff to the Dead Sea. Flash floods are drained into sinkholes (swallow-holes) within these gullies and the water reappears in sinkholes within the mudflats hundreds to thousands of meters away, closer to the shoreline. The rapid inflow and emergence of the water in the sinkholes is accompanied by collapse of the surrounding sinkhole walls thereby enlarging them. As the water is swallowed, additional sinkholes develop in the gullies’ floor only to be filled by the sediments carried by the flood water or from the collapsing walls. Comparison of water travel time in the subsurface between two flood events reveal that it has been significantly shortened. During the weeks that follow each event additional sinkholes develop within the gullies as well as in the vicinity of the outflow sinkholes. These observations suggest that the subsurface salt karstic-like system undergoes rapid development during and following these flood events. In the course of the talk, we will present a film produced from several time lapse cameras (TLC) installed to capture such events.
Estimation of Ecosystem Services improvement in the implementation of deep managed aquifer recharge in Llobregat delta (Spain)

Tuesday, 24 September 2019 11:15 (15)

The recurrent problems in water quality and water scarcity around Europe and more specifically in Mediterranean areas, require the implementation of innovative solutions and related methodologies to assess their impacts in terms of resource improvements and society benefits. The European water research project DESSIN developed a methodology for the evaluation of ecosystem services (ESS) changes associated with the implementation of innovative technological water solutions. The methodology was tested in three urban demo sites across Europe with a specific focus on freshwater ecosystems.

The ESS framework builds upon existing classification systems for ESS (CICES and FEGS-CS) and incorporates the DPSIR adaptive management scheme as its main structural element. This enables compatibility with other international initiatives on ESS assessments and establishes a direct link to the EU Water Framework Directive, respectively (Anzaldua et al., 2018).

This methodological approach to estimate the ESS has been applied in two Managed Aquifer Recharge systems of the Llobregat Delta (Barcelona, Spain): the existing infiltration ponds and the planned deep managed aquifer recharge with prepotable water. In the first case, the study focused on the economic valuation of changes in ESS provision using existing impact data. In the case of deep aquifer recharge the data of changes in ESS have been obtained from column studies and numerical models of groundwater flow. Additionally, information from surveys to local population has been included in the analysis.

The evaluation of ESS changes that the implementation of the deep recharge would bring have included the quantification of drivers and pressures using specific indicators. The main changes are observed in the groundwater quality and quantity (decrease of contaminants and increase of potentiometric levels) but the analysis also reveals the importance of the increased groundwater storage which gives to the water managers more security for water supply to the population. The costs of the technology are lower than the saving costs estimated using the ESS approach. Main savings are related with less energetic costs for pumping and treating the water. But the most relevant saving is the fact that groundwater storage can offer an additional water resource for drought periods. Cultural services are also estimated and monetized. New cultural services, as research opportunities or education, are estimated together with improved cultural services (as landscape) to estimate the economic impact. As a result, in total, it is estimated that the implementation of the deep aquifer recharge would bring savings higher than 4.3 million €/year.
Track Classification: Topic 3 - Groundwater sustainability and governance
An iterative geophysical – geological – hydrogeological approach for high resolution interpretation of ERT profiles. The Siguenza-Guadalajara limestone-marl-sand series case-study (Spain)

Thursday, 26 September 2019 11:45 (15)

Geophysical resistivity methods have been used in groundwater surveys for many years. The resistivity parameter provides important insights on the geological structure and hydrogeological functioning of aquifers, and can be related to types of rocks and soils, clay content, weathering, porosity, water content, etc. The use of the 2D Electrical Resistivity Tomography (ERT) method significantly developed these last years and is used worldwide in various geological contexts. The aim of this study is to highlight the interest of an iterative, collaborative and synchronous work between the geologist/hydrogeologist and the geophysicist to deliver as robust and reliable as possible ERT inversion and interpretation results. The geological context in the survey area corresponds to a Jurassic to Cenozoic limestone, marly and sandy sedimentary series. The Albian (Utrillas) formation (Inferior Cretaceous) is a sandy unit and the targeted aquifer. It is overlain by limestones, dolomites and marls (Cretaceous superior to Tertiary). All formations are folded and faulted. Geological field surveys were performed. The lithological logs of 6 drillings (UTM coordinates around X= 524542 m, Y = 4540163 m) and five ERT profiles, with a total length of 7150 m and a Depth of Investigation (DoI) of about 300 m were available for this study. The resistivity profile described in this paper (P1+5) was performed with a Pole-Dipole array. Then, the calibration process itself began by correlating first ERT inversions with (i) actual geological map (1:50 000), that enabled to set-up a geological cross-section along the ERT, and (ii) borehole lithological logs. The correlation with logs enabled to link resistivity ranges to some lithological units where appropriate. Resistivities up to 1000 Ohm.m correspond to limestones & marly limestones (Senonian/Cretaceous superior). Resistivities between 10 and 220 Ohm.m correspond to marls (Turonian/Cretaceous superior). A low resistivity corresponds to the Utrillas sands. So, a few structures from the geological map (e.g. a syncline) were found reliable. After varying inversion trials, “blocky inversion” (Loke 2003) appears as the most appropriate inversion schema for determining the main layers geometry with minimum discrepancies with regards to the borehole information and geological cross-section. Within this folded sedimentary setting, ERT imaging apply to reliably image the dipping layers of varying resistivity to a limited depth of about 100 m. At greater depth, dipping structures can’t be imaged because of the decreasing resolution of the method. The next step would intend to test inversion parametrization for enhancing resolution of dipping layer at depth. A few correlations and several discrepancies were identified. This iterative hydrogeology – geology – geophysics process was highly valuable. It enabled to elaborate a much more realistic interpretation, that allowed to site a new borehole accordingly.

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Session Classification : Parallel

Track Classification : Topic 5 - Tools, methods and models to study groundwater
In order to use water resources as a need for drinking water; there are permissible limits of the national and international standards for the physical properties of water, and some dissolved parameters in the water. Environmental monitoring should be carried out by regular measurement of these parameters. A large geographical area of Siirt Province located in the southeast of Turkey is mountainous and so rugged and, it may be characterized as a water-rich region. Hesko Spring stands within the boundaries of Siirt Province and supplies a significant part of the water demand of the province. There is not any study in the literature about this water resource which is very important for the province and also, no previous analysis has been made on it. Although the transportation is very difficult, and the land remains in the security zone, it has made the analysis of this spring impossible. Due to these features, Hesko Spring can be defined as a 'hidden spring'. In this study, the chemical analysis of the water samples which were taken during the spring season of 2019 by performing fieldwork were carried out in the laboratory medium. At the end of this study, the results of the chemical analysis of this hidden spring were evaluated.

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Session Classification : Parallel
Track Classification : Topic 8 - Groundwater quality and pollution processes
Spring Development for a Small Village Water Supply: The Story of Ginda B Village, Nigeria

Monday, 23 September 2019 16:00 (60)

Ginda B is a village in Nasarawa State, Central Nigeria which is one of the small villages that benefited from the Conditional Grant Scheme of the MDG’s in 2008. The benefits included the establishment of a Primary Healthcare Centre as well as a solar powered borehole scheme to provide water for the center as well as the village. The village is situated on a hilltop (elevation = 450m above mean sea level) has a population of about 300 people. Due to a challenging terrain (geology and topography) and the remote location of the village it was impossible to provide the solar powered borehole scheme originally proposed. The hill upon which the village is situated is made up of the Nigerian Basement Complex terrain specifically gneisses, but is characterized by a series of fracture springs along the slopes and at the foot of the hill. The most productive of these springs are situated at the foot of the hill. Spring development was proposed as an alternative to provide water to the primary healthcare center as well as the immediate village. In the past, the village had faced a lot of socio-economic challenges associated with lack of sustainable water supply. Women and children old enough spend most of the day in search of water which requires downhill trips to the network of springs, some of which are seasonal. This has negatively impacted on level of education and also economic well being of the villagers. The scheme thus proposed and constructed consisted of a collection point, and infiltration gallery, reservoir/ground tank, a pump house and finally an over head tank adjacent the Healthcare Center. Water from the springs is filtered in the gallery and then stored in the ground reservoir from which a 3hp submersible pump powered by a diesel generator pumps the water to the overhead thank adjacent the Healthcare Center. A reticulation network from the overhead tank was also set up to provide water to the households in the village. Once the reservoir is filled up, it takes 2 hours of pumping to fill up the over head tank which has a capacity of 20,000litres. Pumping is done thrice a week which consumes about 32 litres of diesel (N8, 000 ~22USD). Basic training on routine maintenance of the scheme (such as servicing of the generator) was provided after which the project was handed over to the village. Ten years on, the scheme is a still functioning major challenge faced is breakdown and subsequent repair of the diesel engine that powers the pumps.

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Session Classification : Poster with refreshments
Track Classification : Topic 3 - Groundwater sustainability and governance
Determination of the source of salt contamination using a combination of novel stable isotopic parameters (37Cl, 81Br, 18O and 2H) and tritium to assess the impact on regional groundwater supplies in southern Ontario, Canada

Tuesday, 24 September 2019 11:15 (15)

The application of road salt or de-icing chemicals to southern Ontario roadways has been the standard practice for the past 70 years. Approximately 100,000 tonnes of road salt is used on southern Ontario roadways, and 5 million tonnes is applied to roads across Canada annually. Groundwater protection and management are vital in southern Ontario and are a topic with increased interest as the impacts of road salt application are becoming more widely known and understood. The Oak Ridges Moraine (ORM) is recognized as a regional groundwater recharge area and has an extensive history of groundwater use, with records of approximately 150,000 private and public wells drilled in the region’s watershed. Samples of salts and bedrock brines, in addition to suspected anthropogenic contributors, are compared with groundwater and pore water samples from some regional and municipal wells across the ORM.

Stable chlorine and possibly bromine isotope analyses can aid in the identification of anthropogenic salt contamination in groundwater and help along with other geochemical methods such as Cl/Br mass ratio to identify additional sources of salt contamination. This study attempts to determine what contributes to the presence of chloride in groundwaters of the ORM. The 37Cl isotopic signature of road salt is ±0.2 per mil SMOC and the 81Br isotopic signature ranges from +0.8 to -0.2 per mil SMOB. The standard mass ratio of chloride to bromide (Cl/Br ratio) in the ocean, is about 300 and the value of Cl/Br ratios of deep formation water from under the ORM is lower than 300, whereas the value of Cl/Br ratio of shallow groundwater affected by road salt is greater than 300. In this study, the isotopic value of bromine (Br) ranged from -1.9 per mil to +2.8 per mil, which may be the result of several processes such as road salt dissolution and recharge into groundwater, saline sedimentary formation fluid upward advection from the bedrock and/or organic and microbial release of organically bound bromide from subsurface sedimentary reservoirs. The highest chloride concentrations (800-1400 mg/L) are found at shallow depths and carry the localized isotopic signature for road salt. High concentrations (>200 mg/L) are also found in both older and recently recharged waters in deeper aquifers within the ORM. Some of these waters based on other parameters such as tritium, 18O, and Cl/Br ratios appear to be recent recharge of anthropogenic fluids at depth. Additional high concentrations of salt-contaminated groundwaters appear to be sourced from the upper migration of high salinity bedrock formation fluids based on novel isotopic tools and a lack of tritium.

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Session Classification : Parallel
Track Classification: Topic 10 - Urban groundwater
Investigation of hydrochemical and isotopic tools for identifying recharge areas and groundwater evolution in carbonate aquifers overlain by complex glacial sediments.

Where carbonate bedrock aquifers are overlain by complex glacial sediments, these sediments control the locations and geochemical signature of recharge to the bedrock groundwater system. In these settings, geochemical and isotopic tracer tools that have traditionally proven effective for characterizing hydrochemical evolution in carbonate bedrock aquifers may be rendered ineffective due to geochemical fingerprinting that can develop as groundwater migrates through the sediments of the recharge pathway. Traditional tracer tools are assessed in an 8,000 km² study area in the Early Silurian carbonate aquifers of southern Ontario, Canada. These carbonate aquifers contain significant quantities of high-quality groundwater resources and provide the sole drinking water source to many large cities and private residences. The glacial history of the study area is complex, with the advance and retreat of three ice lobes having deposited sediments that vary widely in permeability, lithology and geochemistry. Results show that spatial trends of higher tritium corroborate with aerobic redox chemistry in the carbonate groundwater systems underlying areas of thin or permeable sediment cover. Groundwater chemical evolution beyond recharge areas is assessed with general chemistry, redox characteristics and an investigation of water-rock interaction. A comparison of strontium isotope ratios (87Sr/86Sr) in bedrock and groundwater shows that long residence times may be required for the isotopic signature of the carbonate bedrock to imprint on the groundwater, though this does not occur consistently. Sulphur isotopic composition (34S and 18O stable isotopic signatures of sulphate) in groundwater was most informative, showing isotopic evidence of pyrite oxidation in recharge areas, and a Silurian sulphur isotopic signature of the host bedrock in areas of thick and low permeability sediments, downgradient of identified recharge areas. The set of tracer tools deemed most useful in this investigation provides the empirical evidence needed to support a conceptual model of recharge and groundwater evolution and is recommended for use in similar settings elsewhere.

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Session Classification : Parallel
Track Classification : Topic 5.4 - Innovative approaches for understanding groundwater flow systems
Spatial modeling of three-dimensional distribution of karstic network in a carbonate rock area

Thursday, 26 September 2019 16:00 (60)

Abstract: Many processes in geologic media, such as water and solutes flow speed and the flow paths, are influenced by the heterogeneity of the medium. Karst aquifers are characterized by this spatial degree of inhomogeneity that strongly affects their hydraulic behavior and transport of groundwater. This study aims to develop a method combines spatial statistics and physical law for the three-dimensional distribution of karstic network in a carbonate rock mining area. A plausible three-dimensional discrete karstic network was constructed using Bayesian hierarchical modeling integrated with geostatistics of conditioning directions (pore throat and connection) and locations of sample pores and cavities at a regional scale. The northern part of the Gejiu tin district, southwest China, was selected, using 1651 samples at five different elevation levels and along a 5km length. Key parameters of this model are spatial coordinates of each pore nodes, size and connective condition of pore throats that form the conduit network. The simulated targets of the karstic network were verified by good correspondence with those of the sample pores and cavities. Our model provides a useful tool to generate plausible karstic networks honor about geology, hydrology, and topography of a real karst system. The model can be used within a groundwater flow framework to analyze flow and transport prediction uncertainty.

Keywords: karstic network, spatial distribution, flow path, geostatistics, Bayesian hierarchical modeling

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Session Classification: Poster with refreshments

Track Classification: Topic 7 - Karst Hydrogeology
Evaluation of Water Information Systems Applied to Groundwater Governance

Tuesday, 24 September 2019 11:15 (15)

Portugal recently faced a severe financial crisis that led to a suspension of funding to water monitoring programmes of the Water Information System (WIS), SNIRH. This caused a severe impact as WIS and shared databases are considered key mechanisms for sharing water basin, country and international policy. This study provides the first empirical assessment of SNIRH performance, in the context of groundwater governance, in order to verify whether the WIS complies with the fundamentals of Principle 5 of OECD Principles on Water Governance. The methodology adopted is based in a refinement of the updated DeLone and McLean Information System Success towards the assessment of a web-based water information system performance in the context of groundwater governance. The model consists of five dimensions: Information Quality, System Quality, System Use, User Satisfaction and Perceived Net Benefits. The analysis and quantification of relationships among the model data collected by questionnaire from 111 users was made through the application of structural equations modelling and multiple correspondence analysis. The proposed model proved to produce good reliability estimates thus demonstrated that the measurement model exhibited a good fit with the data collected. The findings of this research provide important input and implications for the water information systems and for groundwater governance in particular. The paper concludes with a discussion on the limitations and governance areas of improvement that could be addressed in future developments.

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Session Classification : Parallel

Track Classification : Topic 3 - Groundwater sustainability and governance
Numerical simulation of groundwater flow with three-dimensional anisotropic permeability effect

Thursday, 26 September 2019 16:00 (60)

Abstract: The anisotropy of aquifer permeability is one of the important factors that significantly influence the groundwater seepage field. In this study, 4412 fracture measurement data were used to simulate the fracture network of the study area using the GEOFRAC method. According to the geological structure and the fracture network, each aquifer in the study area was divided into different blocks, and the three-dimensional permeability coefficient tensor of each block was calculated. Based on the analysis of the groundwater recharge and hydrogeological conditions in study area, a detailed numerical model of groundwater was constructed, calculated and analyzed. The analysis results indicate that the groundwater movement, which mainly presented by fissure water, is obviously controlled by the permeability anisotropy of the aquifer. The calculation results of the two have obvious deviations comparing the uniform anisotropy model of the aquifer in the whole region. Furthermore, the anisotropy of aquifer permeability has obvious influence on the calculation result of water yield of mine.

Keywords: groundwater, anisotropy of aquifer permeability, the fracture network, permeability coefficient tensor, numerical simulation

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Session Classification: Poster with refreshments

Track Classification: Topic 5.4 - Innovative approaches for understanding groundwater flow systems
A calculation method for three-dimensional permeability tensor in a carbonate aquifer

Abstract: The relationship of permeability and their own fissure development of karst aquifers can be linked by the theory of permeation tensor. The macroscopic karst morphology is developed by microfracture systems, which are the products of a unified regional tectonic stress field acting on similar rocks. And the macroscopic karst morphology and the micro-fracture permeability tensor share similarity and correspondence. In this study, the distribution law in all directions is calculated by investigating the spatial distribution data of macroscopic karst morphology in the study area. Furthermore, the principal values of the permeation tensors calculated from a large number of fracture points are analyzed by statistical regression, and the linear relationship between the main values of the permeability tensor and the calculation equation of the three-dimensional deep tensor are derived. The summary calculation formula is used to transform the single fracture of the core in the borehole into a three-dimensional permeability tensor. The flow field formed by the unsteady flow pumping test of the hole is compared and fitted. After establishing the groundwater flow model. The results show that the method is feasible to obtain a large amount of data compared with the existing permeation tensor estimation and adjustment, it could save the cost of the traditional three-stage water pressure test and other methods and has certain engineering reference for the karst aquifer tensor.

Keywords: karst aquifer, statistical regression, permeability tensor, three-dimensional

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Session Classification: Poster with refreshments

Track Classification: Topic 7 - Karst Hydrogeology
Coastal environments, especially wetlands, provide a valuable range of ecological services. These services benefit nearby communities that often make use of the resources that these ecosystems provide. Climate change and demographic changes can become a threat to their stability and a trigger for inter-community conflict. In this context, the characterization of water resources acquires high importance when determining the vulnerabilities and potential impacts associated with global change.

This study presents a quantitative characterization of the Huaura aquifer and its relationship with the Albufera de Medio Mundo wetland, in the central coast of Peru. A MODFLOW numerical groundwater model was constructed and calibrated to analyse the behaviour of the hydrogeological system. From the water balance analysis, it was possible to determine that the main recharge of the aquifer is related to agricultural activities, while the main discharges are to the ocean. Through the WETSPASS methodology, it was determined that in average, 23% of the water used for irrigation recharge the aquifer.

Two types of simulation were performed. First, a land use change from bare soil to an urbanized area in the surroundings of the Albufera. The simulations showed a small sensitivity from the system to this land use change, mainly because the main recharge to the aquifer comes from the agricultural activity in upgradient lands.

Afterwards, the MODFLOW model was linked with WEAP software to obtain an integrated groundwater-surface water decision support system. Due to the limitations of the study, only a steady state model could be developed. However, since WEAP simulates monthly stress periods, it was possible to link MODFLOW to WEAP and obtain seasonal variations and projections for the climate change scenarios HADCM3-A1, HADCM3-A2 and HADCM3-B1.

This work was framed as a methodological basis for the generation of an integrated DSS that considers surface and groundwater management. Through the input of more information and the creation of a robust database, it will be possible to develop more accurate estimations and improve the information access during the decision-making process of water resource management in Huaura catchment.
Study on non-linear recharge process of karst groundwater from river leakage in the Jinci spring area, China

Thursday, 26 September 2019 16:00 (60)

The Jinci spring is a famous karst spring in north China and the leakage of the Fenhe river has a significant effect on the recharge of the Jinci Spring. However, the mechanism and process of the river leakage into shallow karst aquifer is very complicated due to lack of long-term monitoring for river water and subsurface water, and quantitative characterization of the leakage recharge process.

In 2018, 11 river sections along the Fenhe river have been monitored so as to calculate the amount of river leakage during different river section, in which the influx of the branch stream was considered. Combined with long-term annual data of two hydrological stations along the Fenhe river from 1987 to 2017 a new regression equation of the river discharge and the leakage coefficient was established to calculate the annual average leakage into shallow karst aquifer along the Fenhe river. It was concluded that, the annual average seepage quantity of Fenhe reservoir-Zhaishang section was 0.866m³/s and the annual average seepage quantity of Zhaishang-Saoshi section was 0.574m³/s.

Moreover, we carried out the hydrological dynamics monitoring daily on the rainfall rate, river discharge, groundwater lever of the Quaternary aquifer and shallow karst aquifer from the Luojiaqu to the Longweitou area. In considering of local geological structure and hydrogeological conditions, a three-dimensional heterogeneous karst groundwater model was established to simulates the nonlinear leakage process. The results showed that, the average leakage of Luojiaqu-Suoyu section is 0.95m³/s in 2018. In addition, the biggest loss of the Fenhe river water was at Cema-Longweitou section, so it was inferred that there might exist large faults or broad karst fissures below the river bed in this section. Therefore, if the water supplement project is constructed in the strongly leakage section, it would have a great help to the recovery of the Jinci Spring.

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Session Classification :  Poster with refreshments

Track Classification :  Topic 7 - Karst Hydrogeology
Characterization and modelling of Portoviejo aquifer (Ecuador) in different climate change and socio-economic scenarios

Friday, 27 September 2019 11:30 (15)

The coastal zones are considered vulnerable to the impacts of climate change. Although groundwater is one of the most significant water sources for agriculture and domestic demands in Ecuador central coast, there are limited studies regarding the evaluation of the resources as well as the impact of the aquifers on global change scenarios. Development of adaptation strategies is needed to increase resilience on aquifers systems. During the last two decades, groundwater usage in the coast of Ecuador has increased abruptly due to socioeconomic growth, desertification and drought problems. Aquifers impact assessment studies under global change scenarios are scarce. This study aims to improve an existing Decision Support System (DSS) developed in the framework of ADMICCO project, by establishing the current and future state of the available groundwater resources for Portoviejo city and its areas of influence and identify effective action strategies at the local level that contribute to increase the resilience of the population in the face of floods and droughts. In this study, the groundwater resources of Portoviejo were evaluated by modelling with GMS-MODFLOW. By applying different calibration methodologies, it was possible to analyse the water balances and fluxes of the aquifer. A calibration deviation map was produced to identify the potential areas to improve the calibration and the monitoring network. Finally, scenarios were simulated: 1) ADMICCO future climate change recharge scenario in the wet season, 2) ADMICCO future socio-economic water demand scenario in the wet and dry season and 3) previous scenario plus the implementation of ancestral groundwater management technics. The current study is pioneering in modelling “Ancestral” groundwater management technics integrated with the so-called Manage Aquifer Recharge Technics as an adaptation measure for climate change scenarios in Portoviejo Aquifer.

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Session Classification : Parallel

Track Classification : Topic 9 - Groundwater and socio-economic development in Latin-America
RAPID ASSESSMENT METHOD FOR KARST CONSERVATION ZONE DELINEATION IN INDONESIA

In Indonesia, conflicts of interest between limestone mining and conservation zone in the karst area occurred frequently. The Ministry of Energy and Mineral Resources (ESDM) of Indonesian Republic had stipulated ESDM Ministerial Regulation Number 17/2012 concerning "Karst Conservation Areas". Based on this regulation, the protected karst area is a landscape that has hydrological functions and the uniqueness of eksokarst-endokarst characteristics. However, there is no fixed method for implementing the regulation in Indonesia. This research aims to propose a method for establishing karts conservation zones rapidly and precisely. The study area located in the Karst Karangbolong Area, Kebumen Regency, Indonesia. In this region the community depend on karst springs to meet their clean water needs, the main springs are Kali Sirah and Jumbleng. The research method used is water tracing, cave mapping, and field observations carried out for seven days. Injections of uranine and tinopal were carried out on several ponors/sinkholes that are estimated to be connected to both springs. Fluorometer GGUN FL-30 was installed in Kali Sirah Spring while GGUN FL-24 was installed in Jumbleng Spring. Charcoal bags were also installed on several springs around the study area. The field observations consisted of measurements of lineament direction and thickness of the epikarst zone which used to make 3D topography. Conservation zone area was delineated by observing the water tracing direction and 3D topography. Validation of the area was done by calculating the nomogram Todd.

Water tracing shows that Kali Sirah and Jumbleng have different hydrogeological systems despite their adjacent location. Kali Sirah Spring is recharged by the Pucung Sinkhole-Candi Cave-Jeblosan Cave system while Jumbleng Spring is recharged by the Banjiran Sinkhole. The conservation zone in Kali Sirah Spring has an area of 174 Ha which has a difference of 8% from the nomogram Todd (189.2 Ha). Meanwhile, Jumbleng has a conservation zone of 46 Ha which has a 5.5% difference with the nomogram Todd (48.7 ha). This study shows that water tracing and fields observation can be used to determine the catchment area of karst spring which is then declared as a conservation zone. This conservation zone is still general because it only considers instantaneous flow connectivity so that this zone can cover an extensive area. Further researches to detail the conservation zones can be done by forming a karst aquifers vulnerability map. Nonetheless, this research can be applied to examine karst conflict areas that require rapid solving.

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Session Classification : Parallel
Track Classification : Topic 7 - Karst Hydrogeology
Comparative analysis of karst spring hydrographs using automatic recession methods

Thursday, 26 September 2019 11:30 (15)

Karst aquifers serve as reliable water source for a large portion of the world’s population, agriculture and ecosystems. The groundwater flow in karst aquifers is characterized by a complex interplay of fast and slow flow processes. Automatic recession analysis on large datasets of hydrographs have been of great value to understand hydrological process variability across different catchments, scales and regions. Event-based recession analysis of karst hydrographs has been used to characterize karst aquifers for a long time but, to our best knowledge, automatic recession analysis has yet not been applied for karst spring characterization. In this study, we evaluate the applicability of automatic recession extraction methods for analysing the recession characteristics of a large number of karst spring hydrographs. We use an automatic routine that recognizes changes in the semi-logarithmic slopes of the recession to separate conduit and matrix contributions. That way, we fit the already available karst-specific recession models to calculate the master recession coefficients of the conduit and matrix system. We evaluate the performance of the extraction techniques and the fitted karst-specific recession models by comparing the variability among recession coefficients calculated by different models. The outcome will be used to: (1) provide guidelines for automatic recession analysis of karst systems using adapted extraction methods and karst-specific recession models; and (2) infer the comparative importance of conduit and matrix drainage in different catchments.

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Session Classification : Parallel

Track Classification : Topic 5 - Tools, methods and models to study groundwater
Analysis of groundwater drought propagation in temperate climates using a water balance model and groundwater model

Droughts are mainly caused by periods of reduced precipitation and affect both surface and groundwater resources. This drought propagates to the different component of the hydrological cycle. Meteorological drought propagates to surface water and the unsaturated soil zone and to groundwater. This can result in groundwater drought. Groundwater drought can be defined as a temporary decrease in groundwater availability over a significant period of time. Groundwater droughts present a severe risk for water availability but have not received much attention in scientific literature compared to meteorological and hydrological drought.

This research aims to develop and apply a method for simulating groundwater drought and its propagation in aquifers. The method was developed by combining a water balance model and a groundwater model for simulating groundwater drought. This research is carried out in the Dijle catchment in central Belgium, which overlies the vulnerable Brussels Sands aquifer.

For groundwater drought analysis, time series of the three main groundwater variables, groundwater recharge (R), groundwater level (H) and groundwater discharge (Q), need to be available with a high spatial and temporal resolution. Although data on the groundwater levels (H) are available with a high temporal resolution, this is usually not the case for groundwater recharge (R) and discharge (Q) data. Therefore, groundwater recharge and discharge time series is simulated using a water balance model (WetSpass) in combination with a groundwater flow model (MODFLOW). Next, groundwater drought was evaluated using a threshold method. Threshold functions of the water table are determined in the context of aquifer sustainability. An aquifer sustainability test is done using recharge-consumption time series in which no systematic trend is detected. The result of this research showed that droughts in the groundwater system are greatly attenuated and delayed.

Keywords: Groundwater Drought, Drought Propagation, Threshold method

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Session Classification: Parallel

Track Classification: Topic 3 - Groundwater sustainability and governance
Fusing geological information with hydraulic tomography: Lessons from unconsolidated deposits

Monday, 23 September 2019 17:15 (15)

The accurate assessment of groundwater and its management requires obtaining reliable estimates of hydraulic conductivity (K) and specific storage (Ss). A large number of empirical, laboratory and field techniques have been developed over the last several decades. However, research suggests that Hydraulic Tomography (HT) yields the most accurate hydraulic parameter estimates that can then be used to build robust groundwater flow models. The majority of algorithms used for HT analysis has relied on geostatistics, however, a number of studies have shown that smooth K and Ss estimates are obtained when the inversion begins with homogeneous hydraulic parameter estimates and when data densities are not high. These smooth estimates are not visually appealing from a geological standpoint. One could overcome this by integrating geological data that are typically available through outcrops and borehole logs.

Here, we examine the usefulness of geological data for HT analysis in unconsolidated deposits by: (1) comparing “traditionally” calibrated geological models to highly parameterized geostatistical inverse models and (2) using geological models as prior information for the geostatistical inversion approach. The investigation has been conducted with laboratory sandbox experiments, at a small-scale field site on the University of Waterloo campus consisting of highly heterogeneous glaciofluvial deposits and using data obtained from a municipal well field.

Results reveal that the calibration of groundwater models built primarily with geological data, yields mixed results in terms of model performance, perhaps reflecting the uncertainties in geological structures along the vertical direction and between boreholes. The geostatistical inversion approach without the explicit reliance of geological data yields improved model performance over traditional geological models when data densities are high, although the resulting K and Ss distributions may not be geologically appealing. On the other hand, when geological data are fused with the geostatistical inversion approach, the resulting K and Ss estimates are more visually appealing from a geological standpoint, and that model performance is most robust. Overall, our results suggest the joint use of both geological and pumping test data for HT analysis when accurate geological data are available.

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Session Classification : Parallel

Track Classification : Topic 1 - Groundwater assessment and management
GROUNDWATER PUBLIC SUPPLY BASED ON AN ANCESTRAL SYSTEM OF GALLERIES

Monday, 23 September 2019 15:45 (15)

Traditionally in North of Portugal, in undifferentiated hydrogeological formations, groundwater has been the main source of small populations. The main sources are natural springs and galleries that intercept fractures in hard rock mountains. The subterranean drainage is driven by a fracture network that can be continuous and not largely conditioned by water courses. The recharge occurs through the precipitation that fall directly into the outcropping layers with well-developed and significant fracturing. The year 2017 in Portugal was particularly dry. While some cities like Viseu were at risk of running out of water, others like São Pedro do Sul located in same district never lacked water. Why? Because while the former depended on a single source of water, the Fagilde Dam, which was exhausted, the latter was always provided with water supplied by the hundreds of mines located on the slopes of the mountains. Underlying this situation is the fact that groundwater is a much more resilient resource than surface water and therefore more resistant to prolonged drought periods. Currently, due to the fast technological progress – but not always beneficial to people’s lives - many galleries, were abandoned although since the oldest times, the populations have been supplied with water captured in several galleries evenly distributed in the mountains, which never failed. This article describes the use of an ancestral groundwater supply system in small parish of São Pedro do Sul as a paradigmatic example of a sustainable use of a natural resource. Consequently, instead of building more dams that cause large economic, social and environmental impacts with high costs for the population, we must consider the use of much less demanding Natural Bases Solutions such as the ancestral systems described here, which proven to be efficient for centuries.

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Session Classification : Parallel

Track Classification : Topic 3 - Groundwater sustainability and governance
Impact of Reduced Nile Water Discharge on Flow and Contaminant (137 Cs) transport in Ismailia Canal and surrounding groundwater

The present paper assesses the potential impacts of the expected reduced Nile water on flow and contaminant transport pattern at Inshas area to the northeast of Cairo. The hydrogeologic system has been conceptualized using environmental isotopes and classical techniques. The largely available data and the results of conceptualization have been applied in numerical and analytical tools to model the hydrogeologic system and to simulate its response to the expected reduced Nile water discharge. The interaction between groundwater and surface water has been modeled and the inflow / outflow components have been determined, both on present day conditions and on different percentages of simulated surface water reduced discharge (20%, 30%, 40%). Furthermore, the impact of surface water conditions (flow, velocity, dispersion...) on radio-contaminant (Cs) dispersion and temporal/spatial distribution have been analyzed.

It has been revealed that at the end of the year 2022, the contribution from the canal to the groundwater in the study area will be decreased by 3.5%, 20.2%, and 27.7%, by decreasing the canal inflow by 20%, 30%, and 40%, respectively. This reduced flow will affect the contaminant load of (137Cs) in the groundwater system twice times the expected in case of the non-reduced flow in Ismailia canal at the end of the simulation (year 2038). The profiles of 137Cs concentration variation with time at different velocities and different distance from the contamination source were deduced from the model, revealing that concentration decreases with distance by reducing flow. At the higher velocity which corresponds to the non-reduced flow in the canal the concentration decreases about 3.69 times with increasing distance from 1km to 20km away from the source, during the first 40 hours. On the other hand, at the lowest velocity (corresponding to 40% less in the canal flow) the concentration decreases about 4.62 times plume with increasing distance from 1 km to 20km away from the source.

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Session Classification: Poster with refreshments

Track Classification: Topic 1 - Groundwater assessment and management
The interaction of meteoric waters with sulfides in areas affected by hydrothermal alteration produces acid drainage, which is a major environmental issue. Acid waters typically have a pH in the range of 2-4 and high concentration of metals that could be toxic to most living organisms, even for human health depending on concentration.

In the highest regions of the Andes, extensive hydrothermal alteration zones have been described. Hydrogeologically these regions are important because they are considered as recharge zones and the source of many rivers. Surface water is used by rural and native community for irrigation and livestock activity and, in some case for drinking purposes even if chemical composition may not be suitable for those uses.

In Chile, scientific literature of natural acid rock drainage generation processes and its characterization is scarce. Thus, we studied El Arpa Valley (32°40'S) groundwater to contribute to the understanding of these hydrogeochemical processes in the Andes of Central Chile. El Arpa Valley is a NE-SW basin with a permanent regime that flows from ~3500 m a.s.l. to 900 m a.s.l. where it reaches the Aconcagua basin. In the upper part (study zone) several springs outflow from a wide gossan cap (leached cap rich in iron oxides and sulfurs) host in andesites and volcanoclastic sequences.

We sampled springs (6), surficial (3) and meteoric (3) waters and analyze them for major, minor, trace elements and stable isotopes (δD, δ18O) analyses. Electrical conductivity (EC), temperature and pH were measured in situ. Moreover, mineral identification was performed by X-ray diffraction.

Results show that EC ranges from 48 to 714 µS/cm, measured temperature is between 9.5 to 27°C and pH vary from 3.8 to 7.3. Waters are mostly SO4-2-Ca+2 type and contains significant concentration of trace elements such as Fe (up to 7000 ppb), Mn (up to 1000 ppb) and Al (up to 6350 ppb). By other hand, Ca+2 vs SO4-2 plot indicates that the main process is the anorthite weathering in presence of H4SO4, released from pyrite oxidation. Furthermore, the presence of boxworks confirms the pyrite oxidation. In addition, the identified minerals in gossan cap include goethite, hematite and quartz.

According with the Chilean norm for drinking-water (NCh 409/1.of 2005) and for irrigation water-quality (NCh 1333), the results pointed out that these waters are not suitable for these purposes.

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Session Classification: Poster with refreshments

Track Classification: Topic 8 - Groundwater quality and pollution processes
Acid Mine Drainage Potential Identification in Reservoir of Natural Asphalt, Buton, South East of Sulawesi, Indonesia

Acid mine drainage (AMD) is a well-known environmental problem resulting from the oxidation of sulfidic mine waste (Søndergaard, J. et al, 2017). The effect of acid mine drainage is decreasing pH and quality of soil and water in an environment. The sulfide mineral such as pyrite, marcasite, pyrrhotite, galena, chalco-cite, covellite, sphalerite, and arsenopyrite. Factors that greatly influence the formation of acid mine drainage are sulfide minerals, pH of the solution, H2O, oxygen and Thibocillus bacteria.

Identification of rocks that have the potential to form acid or not are called "characterization". By knowing the distribution of rock types based on their characteristics in the formation of Acid Mine Water, so that a good environmental pollution prevention plan is prepared.

This research was conducted at a natural asphalt reservoir mine located in Buton, Indonesia. The lithology around the site is sandstones, conglomerates, marl, and carbonates. The method used is taking samples of runoff water in rivers and underground water in boreholes, drilling core samples. Sample was carried out laboratory testing, the tests carried out were the values of NAG (Net Acid Generating), pH, TDS (Total Dissolved Solids), Total Fe and Total Mn.

Based on the results of the chemical analysis of NAG in rock samples it is known that the sulfur content is relatively large at around 1.37-4.61 all samples are PAF (Potential Acid Forming), the smallest sulfur value of 1.79 is found in drill hole L560 with a thickness of 9.2 m in Siltstone lithology; equal to 0.44 found in the L780 conglomerate with a thickness of 0.44m; total sulfur is 3.99 in the L160GR conglomerate with a thickness of 5m.

The control of mine acid water in the mining area includes control the oxidation of sulfide minerals by means of wet or dry cover method and neutralize acid mine drainage by adding carbonates that is formed before being drained into the river.

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Session Classification : Poster with refreshments

Track Classification : Topic 1 - Groundwater assessment and management
Development of Integrated water resources management model in the transboundary Cijevna River Basin (Montenegro – Albania)

Monday, 23 September 2019 12:30 (15)

Transboundary Cijevna River Basin is shared by two countries, upstream Albania and downstream Montenegro. Generally, Cijevna is one of the most important rivers for Montenegro, not because of its river flow but because of its water quality and principal role in recharging of aquifers used as a main source for water supply in entire Skadar basin, which is the largest in Montenegro.

Sustainable transboundary water management is one of the highest priorities of the two countries, what is confirmed by signing of bilateral Water Management Agreement, in July 2018. Development and implementation of this Agreement have to be the key point of the established cooperation in transboundary water management. Implementation of ESPOO Convention, Helsinki Convention, as well as Water Framework Directive of the European Union, and other connected water by-laws are all part of signed agreement, and found to be a substance of integrated water resources management on a transboundary level. This Agreement consider that envisaged activities in one country with possible impacts on another, should be subject of discussion between countries, based on scientifically prepared basic data.

The Cijevna River Basin has been previously emphasized as a priority basin for integrated water management within frame of the international GEF funded Dinaric Karst Transboundary Aquifer System project (“DIKTAS”), and its Strategic Action Program (SAP). Basically, within entire transboundary Cijevna River basin the limestone rocks are dominant, and karst and fluvio-glacial groundwater are abundant. An active hydraulic connection between surface and groundwater in this basin is a sensitive factor: Any undertaken works or river training may cause negative implications on groundwater regime, as well as water quality. Currently limited investigation and monitoring of groundwater in this basin have to be improved which will offer an opportunity to develop model for sustainable transboundary water use. Design and establishment of new groundwater monitoring network within the Cijevna transboundary river basin, which should include “early warning system”, and results of new investigations, should enable a base for further negotiations between countries, strategical planning and development of Integrated Water Resources Management. If would result with success, such an approach may be widely used for promoting efficient water management in sensitive karstic areas.

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Session Classification : Parallel

Track Classification : Topic 3 - Groundwater sustainability and governance
The resilience of the Alsatian aquifer, France to climate and anthropogenic change

Tuesday, 24 September 2019 12:15 (15)

The vulnerability of the Alsatian aquifer to climate change and water abstraction has hardly been investigated whilst climate change impacts such as decreasing snowfall, droughts and heat waves are becoming stronger and water abstraction for irrigation is seasonally intensifying as a result. Despite being influenced by a European temperate climate, seasonal drying of springs and streams have been recently observed in the Middle Alsatian Plain and drought decrees in Alsace have intensified. The Alsatian aquifer, an alluvial aquifer located on the French side of the Upper Rhine, is one of the largest aquifers in Europe. It not only provides drinking water to approximately 1.5 million inhabitants but is also a highly important water supply for industry and irrigation. This study aims to improve our understanding of the interactions between groundwater levels of the Alsatian aquifer and river discharge during drought periods. Lying within the Upper Rhine Graben, this complex basin is flanked by the Vosges and Black Forest mountains to the West and East respectively. As such, the aquifer is influenced by both the River Rhine, its main tributaries and the Vosges mountains. At present, it is difficult to differentiate climate and anthropogenic signals in groundwater level lowering. In this study, spatial and temporal correlations of river discharge and groundwater levels are carried out based on meteorological and hydrological data available since 1955 from national and regional agencies, field studies and modelling. A high-resolution analysis at daily time steps is performed at representative sites in Alsace. In a first step, the focus is placed on extreme drought years such as 1976, 2003, 2015 and 2017. Climate change has decreased snow storage and snow water equivalent as well as increasing periods without precipitation and thereby increasing evapotranspiration over the last decades. Even though irrigation represents on average only 26% of groundwater abstraction in the Upper Rhine Department and 11% in the Lower Rhine Department over a territory that is 50% agricultural, water withdrawals are concentrated over a few months and their impacts are visible. First results show a strong link between summer water abstraction for irrigation and drying of streams implying that the impact of water abstraction could outweigh that of climate change during summer droughts. Because they can affect the sustainability of drinking water supply, biodiversity and economic activities, awareness on droughts impacts and water abstraction should be increased.
Track Classification: Topic 2 - Groundwater and climate change
A global dataset of simulated karstic groundwater recharge to support water management and speleothem analysis

Thursday, 26 September 2019 12:15 (15)

Large-scale assessment of karstic groundwater recharge has been receiving increased attention because of the need to support national and international decision making and water policy. Also, the inclusion of above-cave karst recharge processes just recently showed to considerably improve the reconstruction of past climates using speleothem records. However, at many regions or caves, quantitative assessments of karstic recharge are not available. In this study, we present the first results of a large-scale karst recharge model that is applied over all karst regions in the world. As a starting point, we use a previously continental karst recharge model and the World Karst Aquifer Map (WoKAM). The model input (precipitation, potential evapotranspiration) is derived from the Global Land Data Assimilation System GLDAS. Similar to the continental scale model, we use observed latent heat fluxes and soil moisture observations freely available from global data bases for estimating the model parameters. For model evaluation, we use annual averages of stream discharge of catchments that are mainly covered by carbonate rock. Yet uncertain compared to local or regional studies, the simulated recharge volumes derived from this first global karst recharge model will provide valuable information for water management and speleothem interpretation at regions were hydrological measurements are scarce or completely missing.

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Session Classification : Parallel

Track Classification : Topic 7 - Karst Hydrogeology
Saline groundwater generation from paleo-termite mounds in the Buffels River valley, South Africa

Thursday, 26 September 2019 15:00 (15)

Salinisation of groundwater under semi-arid to arid conditions is generally attributed to a three-step process: (1) evaporation rates exceed mean annual precipitation (MAP), leading to (2) formation of a salt crusts on the surface, followed by (3) formation and downward percolation of brines when episodic rainfall is received. Groundwater in the north west of South Africa is variably saline with electrical conductivity (EC) in excess of 4 000 μS/cm. However, much of the coastal zone of southern Africa (including Namibia) has similar MAP profiles and associated high evaporation rates and yet groundwater does not suffer from the same level of salinisation. Moreover, saline groundwater is not uniformly distributed and together these features suggest that other factors leading to salinization are at play. The Buffels River catchment extends over an area of approximately 9250 km² from the elevated interior in the north of the country running down to the coastal plain at Kleinzeer on the north-west coast. The river itself is ephemeral and while a few larger towns receive piped water from the Orange River situated to the north, but most of the smaller local communities rely on groundwater to sustain themselves. Palaeo-termite mounds, known as heuweltjies (meaning little hills), are common surface features along the west coast of South Africa, covering between 14 and 25% of the land surface. They are highly concentrated in zones in the Buffels River catchment. These structures typically consist of salt- and nutrient-rich sediments and the recorded sediment EC values for these structures are an order of magnitude higher than that of the surrounding sediments. One hypothesis is that heuweltjie salts contribute to salinisation of groundwater in areas where the distribution of heuweltjies are particularly abundant. Distinct sulphate rich layers have recently been found within the heuweltjies and may be related to highly variable sulphate concentrations in the groundwater in this area (2 mg/L to 453 mg/L). Groundwater 87Sr/86Sr ratios in this area are extremely elevated, up to 0.78240, suggesting interaction between the groundwater and local radiogenic granitic gneisses. However, groundwater 87Sr/86Sr ratios decrease to the west which could indicate interaction or mixing between different water sources. Highly variable 36Cl/Cl ratios (25.94 x10⁻¹⁵ and 156.19x10⁻¹⁵) provide an indication that groundwater recharge occurs inland and mixing between multiple sources. Radiocarbon activity in groundwater in the Buffels River Catchment range between 22.60 and 100 pMC, providing an indication of varying groundwater residence times and could indicate mixing between multiple sources. 34S and 18O in sulphates as well 14C activity in groundwater and sediments are being used to constrain the source or origin and transport mechanisms of the salts to understand the possible link between heuweltjie salts and groundwater salinity.
Track Classification: Topic 8 - Groundwater quality and pollution processes
Degradation of chloroethene plumes of aged sources located in the hyporheic zone in the presence of co-contaminants with the combination of In-Situ Chemical Reduction methods with biostimulation of the dechlorinating microorganisms

Friday, 27 September 2019 12:00 (15)

This work dealt with the physical and biogeochemical processes that favored the natural attenuation of chloroethene plumes of aged sources located in the hyporheic zone in the presence of co-contaminants, such as nitrate and sulfate. Four working hypotheses were stated:

i) Reductive dechlorination is increased in areas where the river–aquifer relationship results in the dilution of other electron acceptors, the reduction potential of which exceeds that of chloroethenes.

ii) Zones where silts predominate or where textural changes occur are zones in which preferentially biodegradation occurs.

iii) The reductive dechlorination in the hyporheic zone is total when there is a good coupling between reductive and oxidative dechlorinating microorganisms.

iv) The degradation rate of the source can be significantly increased when implementing combined on-site techniques

A field site on a Quaternary alluvial aquifer at Torelló, Catalonia (Spain) was selected to validate these hypotheses. This aquifer is adjacent to an influent river, and redox conditions of groundwater favor reductive dechlorination.

The main findings showed that the low concentrations of nitrate and sulfate due to dilution caused by the input of surface water diminished the competition for electrons between dechlorinating microorganisms and denitrifiers and sulfate-reducers.

Under these conditions, the most bioavailable electron acceptors were perchloroethylene (PCE) and metabolites, which favored their biodegradation. The hyporheic zone represents an important ecotone where reductive and oxidative dechlorinating microorganisms coexist. As isotopic results show, the dechlorination rate in the hyporheic zone is increased because of the low concentrations of co-contaminants, which result in an increase in the abundance of dechlorinating microorganisms.

In addition, the high availability of organic matter and the seasonal mobility of the oxic-anoxic interface of the hyporheic zone favor a good coupling between the dechlorinating communities, which favors the rapid degradation of the most toxic metabolites of PCE, such as cis-dichloroethylene and vinyl chloride detected in the source area.

Microcosm experiments performed at the laboratory scale using sediments and groundwater from the ecotone represented by the hyporheic zone have demonstrated that the combination of In-Situ Chemical Reduction methods with biostimulation of the dechlorinating microorganisms is able to efficiently enhance the rates of dissolution of the source and to increase the degradation rates of the plume.

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**Session Classification**: Parallel

**Track Classification**: Topic 8 - Groundwater quality and pollution processes
The lateral groundwater exchanges from Mt. Maggiore aquifer and Riardo Plain hydrogeological system (southern Italy)

Thursday, 26 September 2019 16:00 (60)

The results of recent hydrogeological researches highlighted the presence of an approximately 500 L/s lateral inflow in the Riardo Plain aquifer from the surrounding carbonate ridges. One of the possible sources of groundwater could be the Mt. Maggiore carbonate hydrostructure, which bounds the Riardo Plain at south.

It is able to store 4.6 m³/s groundwater, 3.6 m³/s of which flows out in correspondence of the Triflisco and Pila springs. The destination of the remaining 1 m³/s of groundwater is still matter of debate. The aim of the present investigation is to increase the knowledge about the hydrogeological settings of Mt. Maggiore and to identify the presence of lateral groundwater exchanges between the fractured aquifer and the surrounding plains through detail hydrogeological surveys over wells, punctual and streambed springs since June 2018.

Monthly chemical and isotopic analysis (2H and 18O) are executed on rainwater samples collected at different elevations (530 and 300 m a.s.l.) and on groundwater samples collected from 4 wells and 4 springs located along the boundaries of Mt. Maggiore. The experimental data are also integrated with the geological, hydrogeochemical and isotopic information available in the previous researches.

Despite to the data acquisition phase is still in progress, it is possible to define some preliminary results that will have to be confirmed by the development of the research:

- The Triflisco spring, monitored from June 2018, is characterized by a mean discharge of approximately 1850 L/s with standard deviation of approximately 150 L/s.
- The Pila spring is dried due to the activity of the well field, located upward on the southern flank of the Mt. Maggiore. Groundwater outflows were still detected downstream the original spring with a mean discharge of approximately 300 L/s.
- 3 streambed springs were identified along the Savone river, but the recharge dynamics are still uncertain.
- The hydraulic head measurements allowed to define different aquifer levels probably related to the presence of different aquifer sections inside the carbonate structure.
- The sampled groundwater showed similar facies and did not highlight differences on the chemical composition.
- The results of the isotopic analyses will give precious information only after a year of monitoring. The preliminary phase of the research does not allow the definition of significant conclusions. The first hydrogeological evidences suggest, anyway, the presence of different sections of the Mt. Maggiore aquifer and different discharge directions.
- A deeper aquifer feeds the basal spring of Triflisco (approximately 30 m a.s.l.), whereas an upper circulation probably flows northward toward the Riardo Plain at an elevation of approximately 110 m a.s.l.

This interpretation needs to be validated in the next steps by the isotopic results and by the structural analysis of the fractured aquifer.
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Session Classification : Poster with refreshments

Track Classification : Topic 7 - Karst Hydrogeology
Comparative hydrogeology – application of quantitative descriptors to groundwater time series with spatial proximity

Monday, 23 September 2019 16:00 (60)

High frequency as well as long-term fluctuations of groundwater levels are the consequence of a large number of different processes within the aquifer system. Groundwater levels are generally influenced both by natural processes (e.g. groundwater recharge, interaction with river systems) and anthropogenic influences (e.g. water abstraction, artificial recharge and piling). Spatial and temporal superposition of these processes cause fluctuations of groundwater levels, referred to as groundwater dynamics, at the position of the well’s screen. Due to superposition, the differentiation between multiple driving forces (input signals) is difficult and requires knowledge of hydro(geo)logical properties of the system. This includes characteristics of the surface, vadose and phreatic zone on different scales. The exploration of all those characteristics is complex as well as time-consuming and, therefore, information are generally only available on a point scale.

In contrast to the limited availability of system characteristics, high-resolution data records of groundwater hydrographs are more generally available. Analysis of high-resolution hydrographs is a frequently applied tool for the prediction of ungauged basins (PUB, e.g. Blöschl et al., 2013; Hrachowitz et al., 2013). The PUB community introduced a number of different quantitative indices to characterize different parts of river flow dynamics. Based on similarities of these indices, river catchments are clustered in groups of similar dynamics and can, subsequently, linked to system characteristics. Due to the various differences between surface and sub-surface systems, the transferability of streamflow indices on groundwater time series might be limited. This study is focused on the question of how transferable these river flow indices are to groundwater time series measured in alluvial aquifers in Bavaria (Southern Germany). More than 50 indices are calculated from sub-monthly groundwater level time series from different regions, with the purpose of covering various hydro(geo)logical settings. The result of hierarchical clustering (Ward Linkage algorithm) of these 50 groundwater hydrographs serves as a baseline. The ability of each index to express hydrograph similarity is quantified. Additionally, the study also analyses the ability of different indices to express similarities of groundwater hydrographs from different regions but with similar hydro(geo)logical settings.

References:

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Session Classification : Poster with refreshments

Track Classification : Topic 5.3 - Advanced modelling tools for subsurface hydrology: from the vadose zone to deep environments
A simple graphical method to visualize the end-member fractions in a three-component groundwater mixing: the example of Ferrarelle system (Riardo, southern Italy)

Thursday, 26 September 2019 12:30 (15)

The Ferrarelle groundwater system (FGS) is located in a highly fractured area in the Riardo Plain (southern Italy) at the base of the northern slope of Mt. Maggiore, covered by a sequence of volcaniclastic deposits.

It is the product of three endmembers mixing: deep mineralized, shallow volcanic and lateral carbonate groundwater inflows. The three-component mixing has been calculated by using V and K which act as reliable conservative elements. The mixing fractions calculated through mass balance were plotted in a element-element triangle plot. This graphic method provides similar results obtained by numerical computation obtained by mass balance.

FGS is mainly governed by the mixing of two endmembers: i) a deep CO2 super-saturated and mineralized (CO2 ~ 0.01 mol/kg; Electric Conductivity ~ 3500 µS/cm) groundwater hosted in the carbonate basal aquifer and ii) a low mineralized (CO2 ~ 0.004 mol/kg; Electrical Conductivity ~ 400 µS/cm) aquifer hosted in the shallow volcanic deposits. Relative fractions of each endmember in mixed groundwater can be calculated by mass balance through an element-element binary plot considering conservative elements in solution. A lateral groundwater input from the Mt Maggiore carbonate aquifer introduces a third endmember in the FGS. The final scenario shows a three-component mixing in a binary diagram where the endmember (components) are located in the three angles of a triangle.

IC coupled with ICPMS analytical techniques provide a large number of variables in the dataset, both major (HCO3, Cl, NO3, SO4, Na, K, Mg, Ca) and minor/trace elements (F, Li, B, V, Mn, Fe, As, Sr, Rb, Ba, Cs), useful to be used for a validation in the mass balance processes. More than 120 groundwater samples were monthly collected from eight wells tapping the FGS since October 2017 in order to test this methodology.

In the FGS the detected end-members are as follows: i) the deep and mineralized aquifer (V 0.2 ppb; K 87 ppm), ii) the shallow, volcanic and low mineralized aquifer (V 15 ppb; K 28 ppm), and iii) the lateral inflow from the Mt. Maggiore carbonate aquifer (V 2 ppb; K 3 ppm).

The three numerical end-members define a triangle plot. We used three equation mixing (for the 3 end-members represented by each side of the triangle.

The final calculated fractions for each sample for the three different end-members, allowed to define the relevance of each fraction on the final groundwater composition in different monitoring well in the FGS area.

V and K seem be the most functional variables to evaluate groundwater mixing in volcanic vs. carbonate water reservoirs in the FGS. Triangulation of mixing functions in the element-element plot allows a fast visualization of fractions of the three components calculated by the numerical mass balances.

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A simple graphical method to visualize groundwater levels in subterranean aquifers

Presenter(s): Dr. CUOCO, Emilio (Università della Campania, Luigi Vanvitelli); VIAROLI, Stefano (Roma Tre University)

Session Classification: Parallel

Track Classification: Topic 5 - Tools, methods and models to study groundwater
Detection and Assessment of Pharmaceutical Drug Residues in Drinking Water

Tuesday, 24 September 2019 12:15 (15)

Recent researches show, how that aquatic environment, which is the source of drinking water, contains anthropogenic substances, until a few years ago, their presence was unknown and there are still considerable knowledge gaps. Emerging contaminants (EC), above all pharmaceuticals and personal care products (PPCPs) are not yet listed in drinking water guidelines because many were undetectable until recently. The development of laboratory methods and procedures and their economic feasibility bring a spectrum of new questions and challenges. An extremely varied range of substances appears in the hydrosphere of which the impact on the ecosystem, and consequently on human health in most cases is unknown. Pharmaceuticals and personal care products (PPCPs) represent a crucial yet manageable group, usually present in very low concentrations in the order of ng/l to ug/l. Their species composition is extremely diverse being mostly made up of different kinds of medicines that enter the sewer after leaving human body. The situation is even more complicated due to the formation of various decay products (metabolites) from primary contaminants. Hormones, contraceptives and even narcotics are also found in water. Livestock and fish farms are another source of pollution, where various products are commonly used for the treatment, prevention of diseases, or to achieve greater weight of animals. These substances are widespread in almost all industrialized and developed countries. The highest concentrations logically occur around large urban agglomerations and medical facilities. Because PPCPs spread primarily in surface water, there are becoming a cross-border European problems.

The main objective of boDEREC-CE project is the design of an integrated management of water works that guarantees increased quality of drinking water. boDEREC-CE delivers a varied range of outputs, based on the knowledge about behaviour of different types of PPCPs in different types of natural environment of CE countries. The first results inside boDEREC-CE projects will be presented, the test area intergranular urban aquifer Ljubljana polje will be highlighted.

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Presenter(s): Dr BRENCIC, Mihael

Session Classification: Parallel

Track Classification: Topic 10 - Urban groundwater
Rising temperatures and dwindling groundwater resources demand significant improvements of water productivity in irrigated agriculture especially in arid regions. In arid regions the prevailing drought conditions are getting harsher. Groundwater resources are mostly nonrenewable and surface water resources are often absent due to low average annual rainfall and high evaporation. On the other hand, the quality of the available water is decreasing rapidly (Ragab and Prudhomme, 2002). The Gulf Cooperation Council (GCC) countries are experiencing these water shortage problems, which threatens the agricultural development (Saif et al, 2014; El-Rashed & Sherif, 2000).

Date palm is a major crop of arid regions, but up to now, only a very small number of investigations systematically explored the relation of yield and water supply for these crops (Car et al, 2012; Sperling et al, 2012; Liebenberg and Zaid, 2002). Also, a more detailed water balance for the root zones from date palms in arid countries is currently not available.

A UPAR grant project 31F057 was conducted in the UAE and demonstrated that commonly used water requirement figures of date palms exaggerate their real water consumption by 20 to 50% and that irrigation schedules of date palms should be based on water stress measurements in the root zone of date palms (Lennartz and Kloss, 2016).

To fully understand the interaction between the irrigation practices and the water balance of the root zone from a date palm a comprehensive soil water model for these crops needs to be set up. Therefore, the aim of this study is to analyze and quantify the dynamic (soil)water processes in the root zone of the date palms during irrigation.

The UPAR grant project 31F057 research provides the data needed to further improve and set up the HYDRUS 2D/3D model, such as soil and climate parameters, soil water variables, irrigation and sap flow data. First, a simple draft water balance of the root zone using a simple bucket approach was made. Then quantifying the deep drainage during irrigation and the water abstraction by the palm. Finally, a detailed soil water model is set up using HYDRUS 2D/3D to indicate the soil water processes during irrigation.

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**Session Classification**: Poster with refreshments

**Track Classification**: Topic 5 - Tools, methods and models to study groundwater
Statistical evaluation of the World Karst Aquifer Map: Global distribution of karst aquifers

Thursday, 26 September 2019 11:45 (15)

The World Karst Aquifer Map (WOKAM), which was completed in 2017, provides the first detailed and consistent global geodatabase concerning the distribution of karstifiable rocks, including carbonate rocks and evaporites, which represent potential karst aquifers and freshwater resources. This study presents the first comprehensive statistical evaluation of WOKAM, focusing on karst in carbonate rocks and addressing four main aspects: (i) Geographic distribution of karst, globally, on all continents, and in the 20 largest countries in terms of surface area and population; (ii) Distribution of karst in different topographic settings, such as lowlands, hills and mountains, and coastal zones; (iii) Occurrence of karst in different climatic zones, ranging from tropical to polar climates and with respect to precipitation regimes; (iv) Estimation of the population living on karst, globally and for individual continents. According to our analysis, 15.2% of the global ice-free continental land surface are characterized by the presence of karstifiable carbonate rock, including both continuous and discontinuous carbonate rock areas. The largest percentage of karst is present in Europe (21.8%), whereas the largest absolute area can be found in Asia (8.35 million km²). China can be described as “karst country number one,” with 26.5% of carbonate rock outcrops, corresponding to 2.55 million km². Globally, 31.1% of all carbonate rock areas occur in lowlands, 28.1% in hills, and 40.8% in mountains. About 151,400 km of the world’s coastline is characterized by the presence of karstifiable carbonate rocks; the most prominent coastal karst areas include the Dinaric karst, Florida, Yucatan and Southern Australia. Karst occurs in all climatic zones. The highest percentage was identified in temperate climates, where 19.1% of the land surface consist of carbonate rocks, whereas less than 9% of the land surface in tropical and polar climates are occupied by carbonate rocks. Last but not least, we estimated the population living on karst areas on all continents and globally, and how this number has increased in the past 15 years. In 2015, 16.5% of the global population, corresponding to 1.18 billion people, lived on karst areas. These statistical analyses demonstrate quantitatively the importance of karst at different scales, help to raise awareness of karst, and provide a common and defendable basis for discussing global water issues.
Using light-weighted geophysical techniques for the rapid ecohydrological characterization of different peatlands in the Alps

Thursday, 26 September 2019 12:30 (15)

Alpine peatlands are valuable but vulnerable ecosystems with diverse hydrological and biogeochemical functions, and they provide habitat for rare and endangered species. Therefore, their characterization requires non-destructive investigation techniques. Furthermore, due to alpine terrain conditions, only light-weighted and robust equipment can be used. We studied two adjacent alpine peatlands of similar size, altitude, and climatic conditions, but with differing topographic and geologic settings resulting in contrasting ecohydrological functioning. The first one is a rainwater-fed bog, the second one is a fen fed by lateral inflow of shallow groundwater from the surrounding slopes. Two simple geoelectrical techniques were applied to obtain rapid geophysical fingerprints of these peatlands: vertical electrical sounding (VES) and self-potential (SP). The clearly contrasting results agree with conceptual understandings of bogs and fens.

The bog VES displays a high-resistivity near-surface layer, corresponding to lowly-mineralized water in the organic soil that originates directly from rainwater. Resistivity in the near-surface layers of the fen is two orders of magnitude lower due to more highly-mineralized groundwater influenced by water-rock interaction. The SP profile of the bog indicates radially-divergent drainage, corresponding to a convex water table, i.e., recharge in the center of the bog and drainage towards the edges. The SP profile of the fen points to lateral inflow from adjacent slopes, corresponding to a convex water table; the fen drains via swallow holes at its northern edge.

The paired-peatland approach made it possible to isolate and identify the effects of ecohydrological functioning on geophysical properties, while eliminating possible differences due to climate, size or altitude. This study also shows that few and simple geophysical measurements can produce relevant insights into the properties of peatlands, which is especially useful for high alpine locations.

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Session Classification : Parallel

Track Classification : Topic 6 - Groundwater, wetlands and natural heritage
A hybrid hydrogeological-geostatistical approach to groundwater monitoring network design in shale gas environments

Friday, 27 September 2019 09:55 (15)

Groundwater resources are vulnerable to the impacts from unconventional gas development. In South Africa there are interests in exploiting shale gas resources in the South Western Karoo region. South Africa offers a unique opportunity to implement a statistically sound groundwater monitoring network in an undeveloped shale gas system. This study presents a design for a groundwater monitoring network using a novel hybrid hydrogeological-geostatistical approach. A multi-criteria decision analysis (MDA) techniques was applied to develop a groundwater vulnerability map, combined with a kriging model to optimize the positioning of monitoring points. Using this approach the existing network was increased from 34 points to 95 monitoring points. The newly designed network shows improvements in the collection of baseline data, specifically in vulnerable zones.

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Session Classification : Parallel

Track Classification : Topic 5 - Tools, methods and models to study groundwater
Characterization Deep and Shallow Aquifer using Stable Isotope $^{18}$O and D. Case Studies from Self Flowing Wells in Indonesia

Tuesday, 24 September 2019 11:45 (15)

Abstract

Stable water isotope $^{18}$O and Deuterium (D) have been widely used in groundwater hydrology, notably to estimate recharge elevation. We analyze water stable isotopes in self-flowing (artesian) wells, prior and after borehole annulus are cemented in order to sample aquifer layers within two categories, shallow or deep. The tested wells are located on the distal plain from different active volcanoes, one in Subang, West Java and the other in Pasuruan, East Java. Both wells have drilling depth ranging from 100 to 120 meters, discharge rates are about 1,500 m$^3$/day and 6,000 m$^3$/day respectively after grouting. Free-flowing occurred when the drilling hit the confined aquifer at depth 65 to 70 meters below the surface. The isotope results from Subang well, value $\delta^{18}$O and $\delta$D before cementing is $-7.5\%$e and $-45.6\%$e and after cementing $-8.0\%$e and $-50.4\%$e. In Pasuruan, prior grouting value $\delta^{18}$O is $-5.8\%$e and $\delta$D $-40.0\%$e and after grouting $-6.3\%$e and $-41.0\%$e. Mixing computations to determine mixing rates based also on hydrochemistry confirm the depletion of the deepest layers as regards the less deep. Temporarily, we conclude two hypotheses; (i) grouted annulus borehole i.e. deeper layers of the aquifer deliver depleted isotope $^{18}$O and D while in the upper layers are enriched. Depleted isotope value mostly scattered nearby the local meteoric water line (LMWL) which means the discharge from the self-flowing well relatively recharged by local rainwater at higher altitude. (ii) in the perspective confined (deep) or unconfined (shallow) aquifer, the deeper aquifer relies more on the depleted water stable isotope and vice versa for shallow one. This approach is still limited at two tested artesian aquifers but, in Pasuruan, as isotope samplings were also performed in boreholes of various depth, comparison of isotopic results with depth will also enable to help draw conclusions that will be presented in the paper.

Keywords: stable isotopes, aquifer, enriched, depleted

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Session Classification : Parallel

Track Classification : Topic 5.3 - Advanced modelling tools for subsurface hydrology: from the vadose zone to deep environments
Adaptive Groundwater Governance Strategy for the Family Farming Sector in the high Andean plateau (Puna Region) of Jujuy province (Northwest of Argentina)

Friday, 27 September 2019 11:45 (15)

The Argentine Puna is a region belonging to the high Andean plateau of South America and corresponds to an intermountain depression located above 3600 meters above sea level. The Puna Region represents 60% of the surface of the province of Jujuy. The climate is cold and dry, with variable rainfall ranging from 50 to 350 mm. These conditions are limiting for agricultural production. In this region a family type of agriculture is carried out by indigenous people. These farmers have access to different sources of groundwater: springs, meadows, wetlands and phreatic water table. In fact, there are many public and private institutions and social organizations linked to groundwater management in the region, which face many challenges in a context of climate change: lack of infrastructure, growing under-financing of public programs, lack of hydrometeorological information networks, insufficient knowledge about the dynamics, structure and functioning of the Puna’s aquifer systems, impact of extreme hydrometeorological phenomena such as drought, among others. In addition, in recent times new actors have been added to the territory, such as mining companies, particularly those that exploit lithium. This situation opens new instances of debate related to the coordinated use of groundwater in the productive processes of these companies as well as in the agricultural production of rural communities. In this work the system of groundwater governance in the Jujuy Puna is characterized other than evaluates its potentials and aspects of improvement with an adaptive perspective in the face of climate change. Existing socio-technical networks were surveyed and the legal and water planning instruments currently in force were analysed. The results of the work shown that the governance system presents opportunities for improvement related to the technical and institutional strengthening of the provincial water authority, the reform and modification of the current regulatory framework, the consolidation of existing socio-technical networks, the mechanisms for effective participation of indigenous communities and social organizations, the formation of local technical capacities and the promotion of social technologies to improve access to groundwater, as well as the protection and conservation of aquifers and high Andean wetlands and the monitoring of water quality. These results were translated into strategic documents for discussion in technical-political decision-making areas such as technical water tables or basin committees in the region.
NOA - INTA) and Department of Planning and Management, Faculty of Nature Sciences, National University of Salta. 

**Session Classification:** Parallel

**Track Classification:** Topic 9 - Groundwater and socio-economic development in Latin-America
Sustainable water resources management: understanding human-water system

Tuesday, 24 September 2019 11:30 (15)

Water research and water management is not only the subject of natural and technical sciences, more and more is important involvement of social sciences. Domestic demands compete with ecology, agriculture, industry and other users for the same water resource. These competitions play out via economic and political mechanisms on scales from the local to global. Water science should be interdisciplinary and it is apparent that water knowledge is produced widely within society, across experts, stakeholders and citizens.

The main objective of Interreg Central Europe project PROLINE-CE is the improved protection of drinking water resources as well as protection against floods or droughts in an integrated land use management. This encompasses minimizing conflicts between drinking water resources protection and land use activities.

Water resources are under increasing pressure, mainly due to land use and climate change which both have significant impacts on water resources in general and drinking water resources particular. The vulnerability of water resources is therefore constantly increasing.

Drinking water protection is already an integrated part of land use management and spatial planning processes, but lagging behind with implementation and realisation. In PROLINE-CE project, from the very beginning the stakeholders and decision makers are involved and participate in the project workshops and other events.

Our pilot action area in PROLINE-CE project is Dravlje valley – the location for potential drinking water source. The pilot action area is urbanized, crossed by highway with large open spaces adjacent to a hilly Natural Park. On this location, in the suburbs of Ljubljana, there is a high pressure on land use. This is also a flood area, where surface waters drainage coming from hinterland is not properly regulated. Despite favourable hydrogeological conditions, there is the influence of existing land use on groundwater vulnerability. As can be seen, the pilot action area is the junction of diverse interests. To harmonise the interests of different stakeholders, that is a prerequisite to establish the drinking water source in the existing land use, we organise workshops, meetings and interviews with involved stakeholders.

We want to present the results and our experiences that have gained in communication and work with stakeholders and decision makers.

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Session Classification: Parallel

Track Classification: Topic 3 - Groundwater sustainability and governance
New approach to assessment of the risk of groundwater contamination by sulphates in karst-fractured Triassic aquifer intensively drained by Zn-Pb ore mines (Poland).

Thursday, 26 September 2019 16:00 (60)

The paper is an extension and development of the previously published paper (Witkowski et al., 2003) and abstract (Witkowski, 2004). Taking into account the results of comprehensive research, including isotopic research, this paper presents a more extensive concept of this assessment. It has been assumed that sulphate load is generating at the land surface and in the extended unsaturated zone and is introduced into the groundwater as a result of a rainwater percolation directly at the outcrops, indirectly through permeable or poorly permeable overburden (Quaternary and Jurassic) or through various (anthropogenic and geogenic) hydraulic contacts between different aquifers or as water seepage from rivers, mainly from Biala Przemsza river. In this context, it was assumed that the four major factors had the greatest impact on the groundwater contamination by sulphates: thickness of the anthropogenic unsaturated zone within the Triassic carbonate series (bigger load from thicker unsaturated zone hosting sulphides of metals), net recharge of the Triassic aquifer (bigger net recharge of the Triassic aquifer - bigger load of sulphates), type of pollution sources at the land surface, hydraulic contacts between different aquifers.

Net recharge has been derived by mathematical model calibration. Maps of the thickness of unsaturated zone, pollution sources and hydraulic contacts were digitised from raster sheets and transferred to the model grid. The point count system model (similar to DRASTIC) has been applied for compilation of the risk map, with the final version produced as a result of computer-based overlays. Five classes of relative risk of groundwater contamination by sulphates were distinguished based on the index values: low, medium, high, very high and extremely high (the higher index value, the higher risk). Reliability of this map was validated against observed concentrations of sulphates in groundwater in the Triassic carbonate aquifer.

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Session Classification : Poster with refreshments

Track Classification : Topic 8 - Groundwater quality and pollution processes
The use of mixing cell modelling to determine transboundary groundwater flow between Malawi and Mozambique:

Monday, 23 September 2019 17:45 (15)

Groundwater has often been described as an invisible resource, yet it is important to recognise that almost 98% of the world’s available freshwater resources are in the form of groundwater. Integrated water resources management (IWRM) acknowledges the important role of groundwater within frameworks that can sometimes be unduly surface water focused. The importance of IWRM is recognised in Sustainable Development Goal 6 'to ensure availability and sustainable management of water and sanitation for all' (United Nations, 2017). Groundwater development is central to meeting this goal. A pressing need though IWRM is to recognise that many aquifers identified for resource use may cross national borders (i.e. through transboundary aquifers). It is then critical that transboundary cooperation comes into play to allow sustainable groundwater of use of these aquifers by those involved.

The current challenge faced by many countries is to accurately define the movement of groundwater through transboundary aquifers and translate this knowledge into management policies (Fraser et al, 2018). Mixing cell modelling can be used to determine groundwater flow through an aquifer system. Based on mass balance between cells, mixing cell modelling is a concept that is easy to understand and communicate. Until now, mixing cell models have not been applied to a transboundary aquifer context however it is believed that they could bridge the gap between science and policy as they can translate hydrogeological science in an accessible format to inform policy.

Malawi is a low-income developing country bordered by Mozambique, Tanzania and Zambia where transboundary aquifer knowledge is limited. The Shire River Basin is shared between Malawi and Mozambique. The Shire River within this Basin is transboundary however to date there is no scientific data to support the conceptual assumption that groundwater also flows across the international border shared between the two countries. This limits management of the resource and thus sustainable use of the aquifers within the Basin.

A transboundary aquifer within the Shire River Basin has been analysed using geochemical and stable isotope data through a mixing cell model. Results indicate that there is indeed transboundary groundwater flow from Malawi to Mozambique and that groundwater interact directly with surface water within the region. Verification of transboundary groundwater flow across the international border will now allow both counties to move forward to cooperatively manage the aquifer and ensure its sustainable development.
Groundwater-Surface water interactions in natural wetlands: a multidisciplinary approach to unravel a neglected issue

Friday, 27 September 2019 12:00 (15)

Wetlands are a vital water resource and ecosystem. However, wetlands are often subject to increased water pressures from anthropogenic sources. One of the missing pieces in the puzzle in much of the research upon wetlands is groundwater-surface water interaction. The quantification of groundwater inputs into a wetland allows stakeholders a greater understanding of the dynamics of the wetland. This aids in the effective management of this vital resource. This study aims to identify wetland groundwater-surface water interactions in the Kafue Flats, Zambia. The Kafue Flats is a large complex system of inland wetlands, listed as a wetland of international importance under the RAMSAR Convention. Remote sensing, hydrochemical and isotopic analysis, field observation methods will be employed. Recent advances in remote sensing technologies such as the Google Earth Engine and associated data catalogues will be utilised. Temporal and spatial changes in multiple multispectral indices will be used to identify the possible surface expressions of groundwater. The chemical and isotopic analysis, as well as hydrometric field measurements, will be performed upon the locations identified by remote sensing as possible groundwater surface expressions. This combined approach will identify and quantify, utilising mass balance calculations the groundwater-surface water interactions of the Kafue flats. The methods employed within this paper will be applicable in the identification and quantification of groundwater dependent ecosystems and wetlands globally.

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Session Classification : Parallel

Track Classification : Topic 6 - Groundwater, wetlands and natural heritage
Global assessment of the impacts of climate variability on total water storage: implications for groundwater resources management.

Monday, 23 September 2019 16:00 (60)

Due to global trends in climate and human activity, groundwater is becoming increasingly more important as a water source. Alongside the effects of climate change and anthropogenic factors, natural climate cycles have considerable impacts on the hydrologic cycle. In particular, they can affect groundwater recharge. However, to date only a small number of studies have sought to gauge these impacts at the global scale and to consider their implications in terms of management and policy decisions. In this paper we look at how global climatic oscillations cycles, like El Niño–Southern Oscillation (ENSO), the Pacific Decadal Oscillation (PDO) and the Atlantic Multi-decadal Oscillation (AMO), affect total water storage and groundwater storage in several large aquifers (area > 100 000 km²) located in varying climatic regions of the world. To evaluate the impact of inter-annual and multi-decadal climate variability on groundwater resources, we look at time series of oceanic indices and compare them to total water storage estimates made from two approaches. The first one is made through the analysis of data from the Gravity Recovery and Climate Experiment (GRACE), which provides information from 2002 to 2017. The second is through a climate-driven model which comprises of two-variables, precipitation and evapotranspiration, that reconstructs past water storage changes from 1980 to 2017. Observed groundwater levels are used to validate these estimates and adapt the methods where possible. Results are expected to show that rainfall patterns connected with the ENSO are the main driver of changes in inter-annual groundwater storage, whereas decadal to multi-decadal variability is believed to be significantly affected by AMO. The combined effect of ENSO and AMO could trigger significant changes in recharge to the aquifers and groundwater storage. These results are aimed at helping to address the threat of water scarcity and the effects of climate variability and change, indicating where more detailed local studies are necessary, and further supply scientific information to support the development of long-term groundwater management strategies of large (in some cases transboundary) aquifers. This study is a contribution to the UNESCO-IHP Groundwater and Climate Change programme (GRAPHIC).

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Session Classification : Poster with refreshments
Track Classification : Topic 2 - Groundwater and climate change
Adapting to water scarcity and climate change in Mediterranean regions: Contribution of the 3D-FEFLOW salinity transport model in the island of Jerba, southeast Tunisia

Tuesday, 24 September 2019 15:15 (15)

The shallow aquifer of Jerba Island is particularly sensitive to sea level rise (SLR) because the island’s relief is very moderate and the altitude of the piezometric surface is close to zero. Seawater intrusion is widespread along the coast, but its amplitude varies from one area to another, depending on the groundwater abstraction rate induced by different economic patterns. The freshwater lens found in the eastern part of the island is likely protected by infiltration from the return of irrigation water and some wastewater.

To meet the expected growth in demand, integrated management of all water resources will be essential (irrigation quotas, infiltration of treated wastewater, import of water from the continent and desalination of seawater).

In this study, we are digitally studying the impact of sea level rise (SLR) through the implementation of a 3D-FEFLOW salinity transport model for the shallow aquifer on Jerba Island. The model was calibrated and validated using data from 1992-2018 and allowed the water balance to be reconstructed.

Changes in groundwater and sea water intrusion have been estimated under various climate change scenarios (RCP 8.5 and 4.5). Recharge, abstraction, discharge into the aquifer, precipitation and groundwater requirements were projected under the same scenarios. For each scenario, piezometric and salinity maps were simulated for the years 2030, 2050 and 2100.

Simulations in the model show that the Jerba aquifer is sensitive to SLR and intensive groundwater abstraction. With the increase in population and economic activity, the long-term sustainability of the shallow aquifer is highly dependent on water balance, which can only be achieved with limited groundwater abstraction and significant imports of water from land or sea (desalination). Increasing agricultural production through irrigation is no longer an option. Nevertheless, sustainable management of the shallow aquifer is still possible, with the aim of preserving orchards (palm and olive trees) and tourist activities that form the basis of the island’s economy.

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Session Classification : Parallel

Track Classification : Topic 2 - Groundwater and climate change
Improving the understanding and influence of small (metric) scale geological features in groundwater flow has been object of interest in the hydrogeological community for decades. In coastal aquifers, geological features such as fractures, sedimentary structures, karstification or presence of dykes, strongly determine the distribution and patterns of saltwater intrusion. Geophysical techniques have been largely utilized in coastal environment and provide large datasets with various resolutions that can be utilized to build and parametrize groundwater models. Here we present an integrated hydrogeophysical study conducted in a coastal site near Belfast, in Northern Ireland. In this area, the presence of volcanic dykes of metric thickness act like low permeability barriers affecting and controlling groundwater flow and saltwater intrusion patterns. To improve the understanding of the system a detailed geophysical survey including electrical resistivity tomography and magnetics has been performed. Modelling of magnetic data provides information about the spatial distribution and geometry of the volcanic dykes. Three-dimensional inversion of electrical data shows a compartmentalization of the groundwater system and the strong influence of the dykes in the spatial distribution of saltwater. All the information is finally integrated in a hydrogeophysical model implemented in a coupled numerical framework using a single code. The approach allows for simultaneous solving of the multiphysical problem. Modelled three-dimensional hydrogeophysical response is compared with observed data. The results significantly improve the resolution of the effect of dykes on groundwater flow as compared to previous independent approaches and clearly show the strong influence of local scale structures in saltwater intrusion.

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Session Classification : Parallel

Track Classification : Topic 5 - Tools, methods and models to study groundwater
Improving rainfall recharge models via drone remote sensing

This pilot study used remote sensing (multispectral and thermal infra-red) by UAV (unmanned aerial vehicle) to improve local rainfall recharge understanding and models at two unconfined aquifer locations, in the North Island, New Zealand. Long-term rainfall recharge lysimeter monitoring sites were existing at both pilot study locations, within these sub-regional aquifer systems. While lysimeters provide accurate information on rainfall recharge to groundwater the data is only accurate at the location of the measurement - the spatial distribution of recharge away from the lysimeter site has uncertainty and is largely informed by soil mapping and water budgets, often at coarse scale (i.e. >100’s m).

Improved characterisation of physical soil properties and rainfall recharge distribution to groundwater is important for both source protection of water supply at the local scale and provision of appropriate groundwater allocation limits at larger scales. Of interest and relevance to this study is the acquisition of high definition soil moisture information via the UAV sensors, and incorporation of this data into existing numerical rainfall recharge and groundwater flow models of these sub-regional aquifers.

The UAV remote sensing provided soil moisture information at centimetre (cm) scale. This high-resolution soil moisture data allowed rainfall recharge (measured at the lysimeter sites) to be extrapolated spatially over the sensed area; and was used to inform the uncertainty of modelled rainfall recharge over the unconfined areas of the aquifer systems. Similar satellite based remote sensing approaches for modelling rainfall recharge to groundwater provide for much wider coverage (i.e. national) but with significantly coarser spatial resolution (i.e. 10’s m).

Of relevance to this study is concurrent work on how the detailed characterisation of rainfall recharge via AUV sensing at the local scale can be used to inform source protection approaches for drinking water supplies with respect to potential pathogen contamination.

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Session Classification : Parallel

Track Classification : Topic 5 - Tools, methods and models to study groundwater
Achieving sustainable exploitation of thermal aquifers based on good governance is a recurrent challenge faced globally. The Pannonian Basin is a clear example, where some neighbouring countries have delineated thermal groundwater bodies, which must be assessed and managed according to the EU Water Framework Directive. In most cases these thermal aquifers are transboundary, necessitating the use of common assessment methodologies, monitoring requirements, and data sharing. As the economies of these countries develop, with growing demands from competing sectors, the need for both cold groundwater and thermal water increases. Boosting the share of renewables within the energy sector generally results in increased groundwater abstraction. This has a negative impact in the transboundary zones where aquifers cross national boundaries.

The international projects T-JAM and Transenergy assessed transboundary thermal aquifers in the Pannonian Basin, proposing improved management goals. The ongoing DARLINGe project promotes a more sustainable, governance-based exploitation of existing geothermal resources in the heating sector which will contribute to an improved energy efficiency and security in the Danube Region.

An innovative benchmarking methodology, developed and refined within this project, provides an easily comparable, informative tool for thermal water management, and its use supports measures for more efficient energy production. The tool has been tested and evaluated in selected transboundary thermal aquifers of the Pannonian Basin using a unified and harmonised approach. Pilot sites were investigated in the Hungarian-Serbian-Romanian, Slovenian-Croatian-Hungarian and Serbian-Bosnia-Herzegovinian transboundary thermal aquifers.

Five main stakeholder groups each with different interests can benefit from this methodology. These are: 1) management authorities, international organizations, 2) licencing authorities, 3) research organizations and universities, 4) investors in geothermal use, and 5) thermal water users. Following the identification of potential beneficiaries ten relevant criteria of the benchmarking methodology were defined.

Five categories of benchmarking indicators are defined: 1) management, 2) technology and energy, 3) environment, 4) social, and 5) economic. The minimum data requirements and data evaluation level is specified for each indicator. The indicators related to management are: licencing procedure, monitoring requirements, monitoring setup and passive monitoring. The indicators related to technology and energy use are: operational issues, cascade use, thermal efficiency, and utilisation efficiency. Environmental issues deal with reinjection, over-exploitation, and the status of water balance indicators. Waste water management evaluation could not be applied in all partner countries due to a lack of current availability of recent monitoring data. The social indicator was tested based on public awareness at site level. An example of an economic indicator is shown on a project level.

For ease of use the tool calculates a final benchmarking number based on indicator types and values.

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How efficient energy production can be achieved and maintained ...
Estimation of water resources from remote satellite sensors

Tuesday, 24 September 2019 16:00 (60)

Most of the Earth’s surface lacks of reliable precipitation and temperature data from meteorological stations. There is a need of an alternative source of data, especially in developing countries with scarcity of hydrological resources. Meteorological data is needed for the hydrogeological studies required to build infrastructures (i.e. agriculture, civil, energetic, ...), implement decontamination solutions, scientific studies, etc. That is why applying indirect methodologies such as satellite sensors, becomes a valuable tool which could enhance human development.

The key information required to elaborate quantitative hydrological analysis at a basin scale are the amount of water entering the system (precipitation), and the possible outlets (i.e. evaporation and transpiration), as well as their temporal and spatial variability. Meteorological stations provide local information and, therefore, the error of extrapolating data to the whole basin is added to the intrinsic error of the station. However, data inferred from satellite information can overcome this drawback by offering a greater resolution of precipitation and temperature data both in time and space. The advantages that remote satellite sensors can offer to water resources studies are: availability of complete, cost-effective, repetitive spatial and temporal precipitation and temperature digital data in remote zones, continuous control and calibration of the data acquiring systems, and an easy and quick application. The obtained results should be calibrated with hydro- and hydrogeological data and compared with other evaluation methods.

Two satellite products, the Tropical Rainfall Measuring Mission (TRMM) and the Atmospheric Infrared Sounder (AIRS), are used in this work. The accuracy of inferring precipitation values from these two products has been evaluated in three zones with different climatic regimes: Barcelona (Spain), El Salar de Atacama (Chile) and Pulán (Peru). Satellite estimates of precipitation and temperature have been verified against data collected from local meteorological stations. Finally, satellite information has been used to estimate the groundwater recharge in the Besòs basin, in the province of Barcelona (Spain).

In this work, we show that satellite derived meteorological data accurately reproduce the seasonal patterns in the three studied areas. It has been proven that satellite and climate models data are a reliable and valuable source of information for hydrological models. They are especially valuable in remote zones, and they constitute a good alternative for the improvement of the water resources management at a basin scale.

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Session Classification : Poster with refreshments

Track Classification : Topic 5 - Tools, methods and models to study groundwater
Smart management of unconfined aquifers in urban areas

Monday, 23 September 2019 17:00 (15)

The water supply of cities presents great challenges since the demand is concentrated in areas where human activities threaten water resources. Where available, deep confined aquifers are protected from contamination. But they often suffer from a lack of recharge and long term withdrawals shall be limited to protect the stock. In contrast, unconfined aquifers usually present greater recharge rates and may be of interest for drinking water supply. Though vulnerable to anthropogenic contamination, such aquifers often present a better quality than surface waters. This study discusses the relevance of using unconfined aquifers in urban areas and investigates the solutions to mitigate their vulnerability to contaminants. The approach is illustrated with a case study in the city of Bordeaux (France). Deep aquifers were subject to overpumping so that unconfined aquifers were considered as an alternative. A flow and transport groundwater model was implemented in a well field vulnerable to a contaminated stream. An adaptive, multi-objective optimization approach was proposed. The objective was to maximize the water production at the well field while minimizing stream water intrusion. The well-field operator can adjust production settings to optimum conditions in function of the observed stream water level and desired production rate. Such a smart use of unconfined aquifers may be advantageous in many cities around the world.

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Session Classification : Parallel

Track Classification : Topic 10 - Urban groundwater
Groundwater management with environmental flows: Hydro-economic models, methods and results

Tuesday, 24 September 2019 11:30 (15)

Originally introduced for rivers, environmental flows refer to the quantity of water that is necessary to maintain valued ecosystems services. This definition has been extended to groundwater dependent ecosystems (GDE) that rely to the occurrence of groundwater. When the natural drainage from an aquifer supports GDEs, increasing groundwater extraction for irrigation may threaten environmental flows. However the protection of environmental flows, as a management objective for a regulating agency, needs to be consistent with the aquifer water balance and the degree of resource renewability. Natural drainage should explicitly appear in the water budget to avoid the water budget myth. In doing so, the long term path of net extraction rate does not necessarily converge to the recharge rate.

In such a context, how can managers of groundwater effectively take into account the maintenance of environmental flows in their policies? And what are the implications in terms of hydro-economic modelling?

To answer to these questions, a stylised hydro-economic model with natural drainage is used to compare the outcome of two management strategies: the optimal control approach and the viability approach. In the optimal control approach, environmental flows are introduced as an externality in the welfare function of the water agency while in the viable approach, environmental flows are modelled as a constraint to satisfy. In both cases, the optimal and viable paths for the water table, water extraction for irrigation and environmental flows are analytically derived together with their long term values. We show how results are sensitive to some key parameters like the discount factor and the weight of the externality in the welfare function in the optimal control approach. We also show how the value of the environmental flows target in the viable approach can be derived from the optimal control approach. Numerical simulations based on the Western La Mancha aquifer illustrate the main results of the study.

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Session Classification: Parallel

Track Classification: Topic 3 - Groundwater sustainability and governance
A multi-method approach to assess the temporal variability of drinking water quality in Sub-Saharan Africa

Friday, 27 September 2019 11:45 (15)

Safe drinking water is of great importance to ensure the protection of public health. Both microbial and inorganic contaminants can be a threat to human health, particularly in Sub-Saharan Africa, where a large proportion of the population do not have access to a treated water supply. This study investigated the temporal variation of drinking water quality over nine months at five rural groundwater sources in Lilongwe, Malawi. The sources comprised three hand pumped boreholes, one open shallow well and one shallow well with a hand pump fitted. Three methods of detecting microbial contamination were employed, comprising traditional incubation, thermotolerant coliform and Escherichia coli culturing methods and an emerging rapid assessment method using tryptophan-like fluorescence technology. Inorganic hydrochemical parameters measured include temperature, turbidity, pH, conductivity, alkalinity, nitrate, fluoride, sulphate, chloride and dissolved organic carbon.

The results highlight the variability of drinking water quality in terms of seasonality and source type, with implications for risks to human health. The different methods of detecting microbial contamination are compared, drawing conclusions on suitability of application and resolution of results. Advantages and disadvantages of the different methods will be discussed in relation to the current World Health Organisation drinking water quality guidelines.

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Session Classification :  Parallel

Track Classification :  Topic 8 - Groundwater quality and pollution processes
Understanding the bacterial community composition of drinking water quality in Sub-Saharan Africa

Thursday, 26 September 2019 16:00 (60)

Contamination of drinking water with bacterial pathogens can pose a risk to human health. Bacterial contamination is commonly detected using proxy indicators such as culturing thermotolerant coliforms and *Escherichia coli* or using emerging technology such as tryptophan-like fluorescence. However, high throughput sequencing of water samples can be used to determine the exact composition of the bacterial community, which can be used to understand the natural variation in groundwater bacterial as well as identify potential sources of contamination.

Bacterial DNA samples were collected from five rural groundwater sources in Lilongwe, Malawi over the course of nine months. The sources comprised three hand pumped boreholes, one open shallow well and one shallow well with a hand pump fitted. The sampling programme captured the end of the wet season, the whole of the dry season and the beginning of the following wet season. Groundwater is relied on most during the dry season and therefore it is important to understand the temporal variation in water quality throughout this period as well as in the wet season when sources may become more vulnerable.

The results highlight the spatial and temporal variation in bacterial community composition between and within the groundwater sources respectively. Results will be discussed in relation to the current WHO drinking water quality guidelines and how detailed datasets such as this can add value to the development of a conceptual model of bacterial contamination and mobility in groundwater.

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**Session Classification:** Poster with refreshments

**Track Classification:** Topic 8 - Groundwater quality and pollution processes
Groundwater quality constraints in the Vieira de Leiria - Marinha Grande aquifer and its implications for water supply (Portugal)

Friday, 27 September 2019 11:15 (15)

Arsenic has long been known for its toxicity, but it has not always been included as a standard parameter in water quality analyses. Arsenic is a natural geogenic groundwater contaminant found in many aquifers around the world and the consumption of groundwater from aquifers with arsenic mobilisation has led to serious health problems in many locations. In Vieira de Leiria – Marinha Grande coastal aquifer in Portugal, the local water authorities have had long standing concerns regarding high arsenic, iron and manganese concentrations in the multilayer porous aquifer used for drinking water supply in the region. Groundwater abstracted from the aquifer frequently shows concentrations of arsenic above the Portuguese drinking water limit (DWL) of 10 μg L⁻¹ As. In addition, concerns about salinization near the coast have been raised due to a steady increase of chloride concentrations during the summer months. Groundwater is the main source of water in the area but its quality is currently constraining its use for public supply.

No hydrogeological or hydrogeochemical research of the aquifer has yet been reported by the scientific community. Consequently, this is the first study of stratigraphic, geochemical and hydrological controls on chloride and arsenic concentrations in the Vieira de Leiria-Marinha Grande multilayer aquifer and the implications for water management and human health.

Groundwater sampling was done in wells for public water supply and in private boreholes. On site measurements in deep boreholes included pH, water temperature (T), dissolved oxygen (DO), redox potential (Eh), specific electrical conductance (SEC, 25°C) and total alkalinity. Measurements were done using an in-line flow cell to prevent aeration. Acidification of sample aliquots ensured preservation of arsenic species. ICP-MS was used to analyse samples for arsenic species, total arsenic as well as major-, minor- and trace elements, while ion chromatography was used to analyse anions. The water quality data was thereafter examined using geostatistical methods and geochemical modelling to understand the origin of arsenic and major geochemical patterns.

The results indicate a geogenic origin of arsenic in groundwater and were used to calculate potential health risks (carcinogenic and non-carcinogenic). Arsenic, iron and manganese values were used to map areas with water quality constraints for public water supply and are used as planning tool for future drilling in the aquifer. EC values, chloride results and chemical ratios were used to identify the areas of saline intrusion risk.

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Session Classification : Parallel
Track Classification: Topic 8 - Groundwater quality and pollution processes
(Un)Sustainability of the current water strategy in Central Serbia

The current water management strategy in the Republic of Serbia (RS) heavily relies on the construction of water accumulations instead of opting for groundwater resources which are, in most cases, available and in abundance. In RS, there are 28 water accumulations with individual volume above 10 million m³. Still, 75% of water supply resources are groundwater with exploitation groundwater reserves assessed between 40 and 60 m³/s just in central Serbia. The real needs of Central Serbia (Serbia without Belgrade, Vojvodina, and Kosovo) are around 12 m³/s for municipal and 20 m³/s including industry (in case that water losses remain below 20%). In 2017, 1.84 m³/s were being used for water supply and irrigation from more than 30 water accumulations in Serbia which accounts for about 20% of Central Serbia needs and way less than these accumulations hold or are intended to provide.

Water management projections in RS date from the 1970s and are based on exaggerated projections of demographical and industrial development and oversized per capita water consumption. The poor economic situation in the last 30 years resulted in prolonged construction of water accumulations and regional water supply systems. A number of operational water accumulations are not nearly used as planned and there are serious sanitary risks.

In 2014, RS has signed to underwent rigorous changes in its water sector due to the "screening" document between RS and EU. Changes were made in Legislation, however, no true progress in the sector has been underwent. Major problems are:

• Lack of coordination in water resource management between different governmental bodies.
• No official representative data on the available groundwater resources.
• Only 10% of the territory is covered with hydrogeological maps.
• National network for monitoring of groundwater resources covers less than half of the territory.
• Most of Central Serbia is poorly covered or only the “first” (alluvial) aquifer is being monitored.
• Only 14% of the population is being connected to wastewater treatment and 2.54% of industrial wastewater is treated. There are over 150 municipal landfills, and only 4 or 5 are sanitary valid.
• Water losses averages are between 30 and 40% with above 70% in some counties.
• The world and domestic experiences with the construction and management of water accumulations point to a high number of techno-economic and ecological risks, high costs of construction and maintenance, water eutrophication, geo-hazards and others.

Still, after all, there is continuing pressure for the use of this water supply concept in Central Serbia. The solution lays in finishing the remaining hydrogeological maps, establishing a GIS water portal and its integration in governmental plans, development of the national monitoring network, repairing of water piping systems and locating and assessment of groundwater reserves.

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Session Classification: Parallel

Track Classification: Topic 1 - Groundwater assessment and management
Assessment of groundwater flow dynamics and water quality in the alluvial fan of Fuego and Acatenango volcanoes, Guatemala

One of the biggest El Niño events ever registered occurred in 2015. In Guatemala, the rainfall values were reduced by 50% in four months of the wet season. This situation caused severe drought conditions in the Pacific basin. The water scarcity situation was managed by the formation of water users boards which successfully promoted dialogue between population and large users of water, the sustainable management of resources and the implementation of surface water monitoring systems. In this scarcity scenario, groundwater has been found to be an alternative for water supply. In countries subject to extreme climatic events such as Guatemala, integrated water resources management becomes an essential tool. To achieve water exploitation sustainability, the understanding of groundwater systems with a scientific basis is required.

This research project aims to generate a regional understanding of groundwater resources dynamics in the geological formation of Fuego and Acatenango volcano alluvial fan, which allows the development of strategies for the appropriate management and protection of groundwater. A field campaign for geophysical surveying and hydrogeochemistry sampling on wells, boreholes and springs was carried out. Interpretation of field data considering geographical, geological, climatic and hydrologic information of the area lead to: (1) the definition of a lithostratigraphic model; (2) the definition and characterization of the main hydrogeological units; (3) the identification of the preferential recharge areas and the calculation of the recharge; (4) the development of a conceptual model of the functioning of the groundwater systems; (5) the characterization of groundwater quality and the main geochemical and anthropogenic processes that determine it; and, (6) the planning of future groundwater monitoring and management measures. It is a pioneer study in Guatemala, with the valuable support of the ICC, which allow the establishment of new groundwater research goals in Guatemala at both local and regional scale.

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Session Classification : Poster with refreshments

Track Classification : Topic 9 - Groundwater and socio-economic development in Latin-America
Contribution to solute transport properties
determination of a karstic formation

Thursday, 26 September 2019 17:15 (15)

In the process of solute transport, dispersivity and hydrodynamic dispersion coefficients are important factors that define the distribution and migration of dissolved salts in the aquifer. Tracer tests were carried out in wells located in the Northeast Coast of Yucatan, Mexico; only the freshwater thickness of the aquifer was analyzed. Sodium chloride (NaCl) was used as tracer. Groundwater flow velocity was estimated with the Drost dilution point method. The analytical model for instantaneous injection is chosen, to analyse solute transport, which is derived from the advection-dispersion equation (ADE), and the dispersivity and longitudinal dispersion coefficients were determined. The results indicate that the longitudinal dispersivity and hydrodynamic dispersion of the aquifer vary from 2.56 to 2500 m and between 1x10^{-3} and 1x10^{-2} m^2/s, respectively. In Telchac Puerto, Dzilam Bravo and San Felipe, advection is the most important solute transport mechanism, while El Cuyo has lower velocity ranges than other locations in the study area and salts tend to disperse. Groundwater flow velocity varies between 3.1x10^{-7} and 8.65x10^{-5} m/s, associated with the flow in the karstic aquifer matrix, with maximum values of 1.5x10^{-4} m/s, associated with the karstification of the aquifer. Groundwater flow velocity increases towards the coast, which is consistent with the fact that the aquifer discharges to the sea. It is observed that in the first 10 m of aquifer the velocities are higher, than those determined in deeper layers, up to an order of magnitude.

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Session Classification : Parallel

Track Classification : Topic 8 - Groundwater quality and pollution processes
Conceptual and numerical groundwater flow models to evaluate construction, geotechnical and environments effects of the Brión railway tunnel for the Ferrol Outer harbor

Thursday, 26 September 2019 12:00 (15)

The railway access to the Outer Ferrol harbor requires the construction of the 5.5 km long Brión tunnel. The tunnel is excavated with the so-called new Austrian method through highly-fractured granodioritic rocks. The tunnel intersects a major fault zone, several fracture zones and two other existing tunnels: the A Graña road tunnel and the A Malata seawage emissary tunnel. The tunnel runs 200 m below the ground surface. Several finite element 2D numerical models have been constructed to evaluate the construction, geotechnical and environmental effects of the tunnel. The numerical models rely on a conceptual model of the hydrogeology of the study area which accounts for a shallow layer of 1-5 m thickness of quaternary deposits and weathered granodiorite, an underlying layer of 10-15 m thickness of altered and decompressed granodiorite, and two deep layers of fractured granodiorites. The deepest layer is assumed to have the smallest hydraulic conductivity. Numerical models of vertical profiles were performed at three representative locations. The models were calibrated first under steady state conditions and then, they were used to evaluate the water pressures at the back of the tunnel, the water inflows into the tunnel and the groundwater drawdowns in deep and shallow wells for several hypotheses about the drainage conditions and waterproofing (undrained, drained and resin injection). Model results have provided very useful recommendations for the Ferrol Harbor Authority.

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Session Classification : Parallel

Track Classification : Topic 5 - Tools, methods and models to study groundwater
Semi-arid regions are characterized by unpredictable intense but short rainfalls and long-lasting drought periods. Particularly in rural Sub-Saharan Africa, this water scarcity leads to marginalization and loss to socio-economic development induced by constant unreliable water supply. Given the limited amount of surface water, groundwater resources are often regarded as an alternative, but more difficult to assess and develop, particularly in hardrock aquifers that characterize much of the Sub-Saharan region. Thick sand beds of wide ephemeral rivers, formed as a consequence of pronounced dryland weathering and erosion, have been reported to present a possibly viable water source, but these so-called sand river aquifers have been poorly studied in terms of dynamics, recharge, evaporation and abstraction potential, as well as their role for groundwater dependent ecosystems such as riparian corridors. In the perspective of finding alternative water resources for rural communities to support current needs and future increased crop production, a portion of the Shashane River in the southern part of Zimbabwe is considered as a case study to characterize sand river aquifers for alternative water storage and analyze their potential in sustaining water supply and food production. Field assessment was coupled with modelling to achieve the objective of this research.

Soil gradation analysis in combination with in-situ slug tests and geophysical assessment were performed to determine the hydraulic properties that define the geometry, storage and flow capacity of the aquifer. Discharge records as well as groundwater level data were used to perform a dynamic analysis on the recharge frequency and the potential water losses from the system. The findings were used to build a 3D transient numerical groundwater model in order to understand the groundwater flow and the natural variation of the storage. In addition, the model was used to estimate the recharge of the system as well as to assess the impact of intensified abstraction scenarios on the storage, flow and evaporation losses from the aquifer.

The aquifer was found to have an available storage capacity of 0.35 Mm3 along the studied stretch of 5.6 km, naturally depleted by 50% due to evaporation when no abstractions occur. Less water is lost to evaporation when abstractions increase, and the system has the potential to fulfill a total demand of 800 m3/day without failure, which can irrigate a potential area of 3.5 ha per km. Despite the increased abstractions, fast and complete recharge in the following wet season is almost certainly ensured by infiltration from surface runoff, except for some extended dry years that occur once every 20 years. Increased recharge induced by abstractions leads to a reduction in runoff in the following year and thus may affect other users downstream, including dependent ecosystems, which requires further studies.

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Session Classification : Poster with refreshments
Track Classification: Topic 1 - Groundwater assessment and management
Assessing the Wildfires impact on groundwater quality: the fire of Doñana Natural Area in 2017

Tuesday, 24 September 2019 16:00 (60)

One of the main risks associated with wildfires is the affection of superficial and groundwater resources. There are numerous disturbances that occur both in the quantity and the quality of the water resources. From this perspective, possible alterations that have occurred in the groundwater chemical composition have been evaluated as a result of the Peñuelas forest fire (or wildfire), occurred in Moguer (Huelva) in June 2017, affecting large areas of the Natural area of Doñana (END). With this aim, during the period 2017-2018, a monthly hydrochemical sampling campaigns were carried out for 21 points (wells, boreholes, springs and lagoons) located inside and outside the fire perimeter. The results obtained in this work show in general a slight increase of electrical conductivity and pH, as well as high contents of iron, manganese, aluminum and silica. However, there are no significant changes in magnesium contents, with some exceptions, just as it was observed in other case studies. Finally, the behavior of other minority elements is being analyzed, paying special attention to the content in Zn, and Se. These elements could be used, individually or in combination with other parameters, as indicators of the impact of the wildfires on the groundwater quality.

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Session Classification : Poster with refreshments

Track Classification : Topic 8 - Groundwater quality and pollution processes
Enhancement on the hydrogeological data management and analysis

Monday, 23 September 2019 16:00 (60)

The conceptualisation of a groundwater system involves continuous monitoring and evaluation of a large number of parameters. All these datasets collected and generated to perform a groundwater conceptual model are often stored in different scales and formats (e.g., maps, spreadsheets or databases) from different entities. This continuous growing volume of data entails further improving on how it is stored.

One of the pillars of effective data governance is data management. Data management is successful when data are: harmonised collected, structured stored, error checked, available, understandable and reusable ensuring maintenance of the data model. There are several developments to stewardship information and they can be implemented in industry, government and academia reducing times and resources to perform environmental analyses. These kinds of data infrastructures and their governance are becoming more mature worldwide because of their importance in ensuring sustainable resources. Data infrastructures, such as spatial data infrastructures, and their governance are continuously being used and developed because of their impact on groundwater management. In addition, these kinds of data infrastructures currently require information communication technology (ICT) tools for improving geodata governance by delivering quality information to users and helping them perform further analyses on a unique platform. To implement these data infrastructures or to connect it to ICT tools is essential an optimal data migration and integration (DMI). DMI also is useful for decision-making with clean high-quality data, which produces a more confident and stringent groundwater governance. To ensure an optimal DMI, it is valuable to provide frameworks with which to assist and facilitate processes to connect and transform multiple systems from different sources and formats to the required destination formats of new systems. Facilitation of how the connections among system structures and the organisation of a DMI model in terms of its application and maintenance should be as intuitive as possible.

We present a methodology to facilitate and optimise DMI to improve data governance. The implementation of this DMI methodology facilitates merging multiple sources of information, installing new systems to exploit stored information while using the original systems of information storage, and upgrading databases, formats or standards that may not be supported in the future to one that is supported or most appropriate, among other processes. The outcomes of its application by the Barcelona City Council (Spain) are used to optimise the groundwater management in the city. DMI models performed in this application can be easily adapted to other external datasets, increasing the volume of quality data to improve the understanding of the groundwater system behaviour and the monitoring network in the city. The proposed methodology can be widely implemented in any kind of DMI project to develop data infrastructures or to implement ICT tools for further analyses.

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**Session Classification**: Poster with refreshments

**Track Classification**: Topic 1 - Groundwater assessment and management
Numerical analysis of periodic transient contaminant-leaching episodes in the unsaturated zone

Monday, 23 September 2019 16:00 (60)

The concentration of contaminants in groundwater underneath landfills and mine tailing piles and treatment facilities increases when the water table rises sharply due to recharge events or the rise of the level rising a neighbor rivers connected to the aquifer. Reactive contaminants may persist for long periods of time due to mineral precipitation and sorption reactions. Here, we present a numerical 2-D flow and solute transport model in a vertical plane to study the leaching of uranium from the unsaturated zone underneath a uranium tailings pile. Model results show that the uranium concentration increases linearly when the leachate flux increases and the upstream flux and the upstream flow of unpolluted groundwater decreases. The concentration of uranium increases in response to the rise of the water table. The peak of uranium concentration takes place about 40 days after the maximum water level in a point located 30 m downstream the uranium source.

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Session Classification : Poster with refreshments

Track Classification : Topic 5.3 - Advanced modelling tools for subsurface hydrology: from the vadose zone to deep environments
Agro-economic Model for Non-perennial Canal System under Partial and Complete Lining Scenarios: Case for Greater Thal Canal, Punjab Pakistan

Greater Thal Canal is projected in an arid region of Pakistan where crop water requirements are accomplished by rainfall and ground water pumpage with low crop yields. An agro-economic model (Indus Basin Model Revised) has been incorporated to optimize water management options for better agricultural output. Model simulations for non-perennial canal system under partial lining scenario posed net water requirement at canal head as 2368 kaf, which is less than the canal water availability (2496 kaf) at 80% canal efficiency while modeled complete lining option demonstrate the net water requirement at canal head as 2460 kaf which is near to the canal water availability (2496 kaf) at 85% canal efficiency. The annual net recharge trough canal seepage to the ground water system has been estimated as 1226 kaf, which is 200 kaf higher than the partial lining option. By assuming partial canal lining option, a ground water recharge of 1326 kaf is estimated while total recharge from all resources is optimized as 2154 kaf. In regard of complete lining option, a ground water recharge of 1128 kaf is expected. The predicted annual rise in water table is 0.9 meter in both partial and complete canal lining options. Simulated annual recharge is an attribute of increase in seepage from watercourses, increase in crop area and a decrease in groundwater pumpage. This rapid rise of groundwater table in complete lining system may result in creating water logging conditions while partial lining system can be adopted under increased cropping intensity.

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Session Classification : Parallel

Track Classification : Topic 1 - Groundwater assessment and management
Permeability modelling using pressure match of well tests and interference tests. A case study in an anisotropic reservoir, the Céreirède observatory.

Thursday, 26 September 2019 16:00 (60)

In order to efficiently model fluids flows in heterogeneous reservoirs, one must inevitably face the problem of correctly estimating parameters for the equations governing the flow. Reaching this objective requires to use different types of measurements or interpretations, acquired at different scales and through time, driven as much as possible by auxiliary data, such as geological concept and seismic imaging. However, the access to all those data in the same location and at the same time is usually not possible, leading to a high uncertainty for the numerous flow parameters. Observatories in groundwater reservoirs are a new way to use analogues in the petroleum industry, as: 1) they offer an easier accessibility to the reservoir than buried oil fields; 2) they allow simplifications of this problem, thanks to single phase flows.

On the Céreirède experimental site (Lattes, Montpellier, South of France), a unique playground was offered to face the question of quantifying the permeability anisotropy in a fluvial depositional analogue. 14 wells were drilled in a 50 x 50 m area (about the surface of one gridblock in a petroleum reservoir model), with an inter-well distance ranging from 2 to 20 m. The shallow water-bearing reservoir is composed of 2 meters of unconsolidated and very permeable gravels belonging to quaternary alluvial sediments.

Well tests and interference tests were conducted on all 14 wells. Pressure Transient Analysis (PTA) of reservoir pressure behaviour provided permeability and other related information on reservoir architecture (such as no flow boundaries or lateral permeability changes between wells). A trend in permeability was observed from South-East to North-West of the site, and anomalies of the pressure evolution showed an anisotropic behaviour. An electrical survey was also conducted, showing an abrupt change of resistivity from South to North.

The integration of all these data through a 3D geological model of the Céreirède site was carried out. At a first step, a simplified transmissivity map was painted in the model from ground observation, to initialise the dynamical simulations. Then a direct inverse method, the DSM ”Differential System Method” was applied. This technique allows the computation of the transmissivity field in a confined aquifer when several “independent” data sets are available, (Parravicini et al. (1995) and Giudici et al.(1995)). Following calibration and sensitivity analyses, the model was tested by matching the pressure history using a pressure solver. The workflow based on a loop process delivered the updating of the permeability model. At the very end, a very good match between simulated and actual water table evolution was obtained, with a permeability field very consistent with the depositional scheme of the sediments.

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Session Classification: Poster with refreshments
Track Classification: Topic 5.1 - Dynamic Analogues
The importance of fluid flow system evaluation in the understanding of hydraulic trapping of hydrocarbons – Case study of Hajdúszoboszló and Ebes gas fields, Hungary

Groundwater flow mobilises, transports and accumulates hydrocarbons, thus the evaluation of recent fluid flow systems contributes to the mapping of hydraulically favourable places for hydrocarbon trapping and preservation. The aim of our research was (i) to understand the recent fluid flow systems and regional pressure field in the broader area of Hajdúszoboszló and Ebes, Hungary, (ii) to find potential areas for hydraulic trapping in the study area and (iii) to explore the hydraulic connection between Hajdúszoboszló and Ebes gas fields and their surroundings.

First the hydrostratigraphic build-up was determined based on borehole sequences, seismic horizons and sections. Then mapping of the fluid-potential field was carried out from measured hydraulic (pressure and hydraulic head) data by pressure vs. elevation profiles, tomographic fluid-potential maps, and hydraulic cross sections. This evaluation was complemented by water chemical and temperature data analyses by TDS (total dissolved solids content) and temperature vs. elevation profiles, tomographic isoconcentration and isotherm maps, as well as cross sections.

As a result of the data processing, two distinct flow systems were identified and characterized, namely the nearly hydrostatic, gravitational, and the overpressured flow systems, which are well known in the Pannonian Basin. The connection between the flow systems and the areas of Hajdúszoboszló and Ebes gas fields were analysed in detail. The favourable hydraulic conditions of entrapment and accumulation right here are provided by coincidences of different factors. Namely, in the area of the Hajdúszoboszló gas field upward gravity-driven flow dominates from the elevated Pre-Neogene basement, which may focus flows of the underpinning overpressured system from the South, up to the land surface. This upward flow zone could force the dominantly horizontal SW-directed gravitational flows to turn upward, whilst pressure and temperature drop, as well as salinity increase and these together decrease the solubility of hydrocarbons in groundwater.

Furthermore the differences related to the topography of the Pre-Neogene basement between the Hajdúszoboszló–Ebes High and the Derecske Trough were took into consideration, as they determine the pressure and heat dissipation and secondary migration pathways for hydrocarbons as well.

These conclusions demonstrate the significance of hydraulic studies in the understanding of secondary hydrocarbon migration and accumulation. Combining these methods with the commonly used practice in industry as a hand-in-hand experience, can help to reach better scores in hydrocarbon exploration.

These results are contributing to a project that has received funding from the European Union’s Horizon 2020 research and innovation programme under grant agreement No 810980 and was supported by Vermilion Hungary Ltd. as well.

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Session Classification : Parallel

Track Classification : Topic 5.4 - Innovative approaches for understanding groundwater flow systems
ENVIRONMENTAL ISOTOPES CONTRIBUTION TO THE CHARACTERIZATION OF THE FLOW PATTERN OF A LARGE PLAIN HYDROGEOLOGICAL SYSTEM: BAJOS SUBMERIDIONALES (SOUTH AMERICA)

Tuesday, 24 September 2019 16:00 (60)

Bajos Submeridionales (BBSS) is an extensive region (54 280 km²) on the Chaco Austral in Argentina. Mean annual precipitation is 950 mm, ranging from 400 mm/y to 1600 mm/y due to the occurrence of hydroclimatic extremes. Potential evapotranspiration reaches 1500 mm/y, and mean annual temperature is 21°C. From a geomorphological perspective, it is located at the distal portion of the Salado del Norte river alluvial mega-fan. It presents a smooth NW-SE slope. Land depressions are occupied by permanent or semi-permanent lagoons. Northwestern surface water divide is located on the Otumpa Hills, an uplift block emerged as a result of regional neotectonics movements. The regional bound of the hydrogeologic system is unknown. It could extend from a recharge zone on Subandinas mountain range on the West end of the region, up to a regional discharge level imposed by the Paraná River on the East end. As is typical on large plain hydrogeological systems, local recharge/discharge vertical flows condition the flow pattern, though slow, regional, chemically evolved flows exist. Intermediate scale flows do not play a relevant role due to low topographic gradients, less than 1 0/00. All flow types discharge locally in numerous surface water bodies and crypto-wetlands, and their interaction is dependent on hydroclimatic pulses. These flow features make difficult to contrast Toth’s hydrogeological conceptual model proposed for sedimentary basins. Nonetheless, some previous works postulated the validity of this model, although with limited field contrast, while others indicated an hydrochemical evolution that can be considered consistent with this conceptualization. A new geological interpretation of the regional system allowed defining consistent hydrogeologic regional units that assisted a new hydrochemical study. Preliminary environmental isotopes results (18O y 2H) presented in this work enabled establishing a complex and sectorized hydrogeologic flow system for the BBSS. In the Southern portion, water circulation would correspond to the current alluvial mega-fan of the Salado del Norte river, with recharge originating on the Subandinas mountain range. In the northern portion, it would correspond to local flows, with a likely contribution from deep thermal flows. Both sectors would discharge into the Salado del Norte river, and finally, into the Paraná river. This sectorization would highlight that the uplift of the Otumpa Hills, which occurred after the formation of the mega-fan, conditioned its primitive flow pattern. Besides, results have shown the strong influence of climatic conditions on water chemistry.

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Session Classification: Poster with refreshments

Track Classification: Topic 5 - Tools, methods and models to study groundwater
ORIGIN AND CHARACTERISTICS OF GROUNDWATER IN THE OZAMA WETLANDS NATIONAL PARK BASIN, DOMINICAN REPUBLIC

Friday, 27 September 2019 12:00 (15)

The hydrological and hydrochemical conditions of groundwater-related wetlands may vary greatly both spatially and temporally depending on multiple variables: the size, location and lithology of the recharge area; the zone of the wetland where groundwater discharge takes place; the magnitude of this discharge and its chemical composition; the regional and local distribution of the hydraulic permeability; the topographic features around the wetland; the contribution of other water sources; the variability of all these conditions; etc. In the framework of a project of the MESCyT to know the functioning of the Ozama Wetlands National Park (OWNP, with about 48 km2), hydrodynamic, hydrochemical and isotopic studies are underway since 2017 to understand, among other things, the relationship between the wetlands and groundwater. In this paper we present some results of the piezometric, hydrochemical and isotopic studies of river water and groundwater in the basin (about 2700 km2) of the OWNP. The main results indicate that regional piezometric levels and main groundwater flow directions are controlled by the Ozama River, which is the main course and drainage axis of the basin. The Ozama River contributes and exports water to/from the OWNP. To the west of the OWNP, groundwater discharges to the wetlands, while to the east are the wetlands that recharge the aquifer. This situation seems to be influenced by the intense exploitation of groundwater that occurs east of the OWNP, mainly for domestic supply. The chemical composition of surface water is mostly HCO3-Ca type, while groundwater samples have two main facies, HCO3-Ca and Cl-Na, with a certain proportion of mixed samples. The HCO3-Ca facies is the lithological signature of the carbonates, which are the most abundant minerals in the basin. The Cl-Na facies is due to the mixture with seawater in the aquifer, since a good part of the sector to the east of the OWNP is affected by marine intrusion. Quite a few water samples of rivers and wells are isotopically enriched by evaporation. Groundwater samples that are mixed with seawater are also enriched for this reason. The isotopic composition of surface waters taken at the source of rivers has allowed us to identify the possible altitudinal isotopic gradient and also to deduce that there are two groups of wells that tap groundwater recharged at two different altitude ranges. This information can be useful for the management of the aquifers. For logistical reasons, the study of the wetlands themselves has begun recently.

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Session Classification: Parallel
Track Classification: Topic 9 - Groundwater and socio-economic development in Latin-America
Simulation of Borehole Heat Exchangers using MODFLOW-USG and USG-Transport

Thursday, 26 September 2019 11:15 (15)

Borehole heat exchangers (BHEs) are increasingly being used to control temperature in buildings. A typical BHE consists of a long U-shaped tube encased in grout, emplaced 100s of meters below the ground. Heat is transferred from the groundwater through the grouting material to the fluid in the tube which is used for temperature control of the building.

MODFLOW-USG is an open source, public domain code released by the US Geological Survey for simulation of groundwater flow. Unstructured grids along with a Connected Linear Network (CLN) package for simulating interconnected conduit features provides the code with exceptional flexibility for simulating subsurface complexities. USG-Transport is an open source, public domain software that includes several enhancements to MODFLOW-USG including capability for simulating density dependent solute transport and heat transport. This is ideally suited for simulation of Borehole Heat Exchangers (BHEs) – unstructured grids provide the capability to focus resolution on the grout and CLNs provide the ability to simulate the BHE tubes. Additional boundary conditions have been implemented for BHE inflow/outflow temperature requirements. The capability has been tested against other solutions and an application example is presented to demonstrate use of USG-Transport for simulation of BHEs.

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Session Classification : Parallel

Track Classification : Topic 5 - Tools, methods and models to study groundwater
Groundwater flow and solute transport models to assess and mitigate the environmental effects of the Sardas site in Sabiñánigo (Huesca, Spain)

Thursday, 26 September 2019 15:30 (15)

The actions undertaken by the regional and national environmental agencies have provided good results for the remediation and containment of contaminants at the INQUINOSA lindane-affected sites in Sabiñánigo (Huesca, Spain). Lindane is an isomer of hexachlorocyclohexane which was a widely used pesticide in the past. Lindane-production wastes were disposed at the Sardas and Bailín landfills. The Sardas landfill is located near the Gallego river. The landfill was sealed in 1993. The quality of the Gállego river water is monitored in a daily basis. Thanks to the remediation and containment actions implemented by the Aragón Regional Government, the Gállego river water meets all the standards for water drinking (Fernández et al., 2013). Here we present a hydrological water balance model of the site to evaluate the groundwater recharge and the water inflows and outflows to the Sardas landfill. We also present 2D numerical groundwater flow and solute transport models along a vertical profile of the site. The steady state flow model confirms the prevailing conceptual model of the site. The transient model corroborates that the underlying Larrés marls prevent groundwater flow, except in shallow layer (< 5 m thickness) where the marls are fractured decompressed and altered. The average groundwater flow underneath the bentonite curtain is about 20 m$^3$/d. The hydrogeological conditions downstream the landfill are strongly affected by the periodic oscillations of the nearby Sabiñánigo reservoir. The models have contributed to deepen the knowledge of the hydrogeology of the site and provide useful tools to screen future studies and remediation measures.

References

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Session Classification : Parallel

Track Classification : Topic 8 - Groundwater quality and pollution processes
Water balance as a tool for sustainable management of karst aquifers – example of the catchment of the Malenščica karst spring (Slovenia)

Thursday, 26 September 2019 12:15 (15)

Karst aquifers can be quite complex regarding structure and water flow. To characterize them properly and to better understand their functioning, one needs to monitor them continuously in various points, such as springs, ponors, water-active caves and surface streams. The Malenščica karst spring is one of the most important water sources in Slovenia, and provides water for more than 22,000 people. The catchment covers almost 800 km² large binary karst aquifer recharged by both an allogenic and autogenic component that can vary depending on the hydrological conditions. The allogenic inflow coming from upstream located poljes makes the water resource quite vulnerable to contamination during medium to high flow conditions. On the other hand, an assessment of volume of autogenic water available during low flow is crucial for the local water supply.

A dense monitoring network was set up in autumn 2016. Autonomous data loggers measuring water pressure, temperature and electrical conductivity in 30-minute intervals were installed at six springs, four ponors, three surface streams and seven water-active caves. In addition, two rain-gauges are measuring precipitation at the same time interval. The data collected in the period from October 2016 to September 2018 were then sorted out and combined with hydrological data of the Slovenian Environment Agency and manual measurements of water discharges to elaborate several rating curves. This allowed quantification of discharge components, constructing a water balance of the whole aquifer depending on the hydrogeological conditions, in order to determine the influence of different types of recharge, and to assess recharge-discharge relations.

The results improve the current understanding of the investigated aquifer, and show the importance of considering temporal variations of drainage area in hydrogeological studies. The results can further be used for risk assessment of the karst aquifer and protection strategies of drinking water source.

Key words: karst aquifer, autonomous measurement, water balance, hydrologic variability.

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Session Classification : Parallel

Track Classification : Topic 7 - Karst Hydrogeology
Methods to evaluate aquifer recharge in Spain for water planning

Monday, 23 September 2019 15:00 (15)

Aquifer recharge is one of the most difficult water balance terms of a given territory to be accurately evaluated. But its knowledge and variability are essential for water planning to attend the human and ecological needs. Recharge is not an independent value for a given aquifer when water exchange between aquifers and other water bodies are significant as in this case the value depends on other factors such as the estate of water exploitation. Recharge evaluation has a high dependence on spatial and time scale, and the different methods available in a given situation do not yield results that are conceptually equivalent. So, calculations have to be carefully done and compared.

In Spain, a relatively large effort has been done at peninsular, hydrographic district, river basin, aquifer and local scales in this regard. This is presented in the report RAEMIA (Aquifer recharge, methods and water isotope support. Application to water planning and knowledge of groundwater in Spain), just finished and under publication as an open-access e-book, produced by the Technical University of Catalonia and sponsored by CETAQUA and SUEZ. This report deals with the different recharge evaluation methods currently available, including those based on hydrodynamic and water balance concepts and on natural tracer studies and mass balance. These methods include the support on satellite data. The supporting examples are worldwide, with special reference to Spanish ones and also the application in Ibero-American areas. The application to water planning and the experience in different peninsular and island areas are summarized and commented. Special consideration deserves the different large spatial scale models and atmospheric chloride ion deposition balance. The report tries to contribute to the open discussion on the validity of the different models, discussion which is lively in water scarce areas, considering that scarcity is mostly an excess of water demand in highly agriculturally productive areas or exposed to increasing pollution

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Session Classification : Parallel

Track Classification : Topic 1 - Groundwater assessment and management
Pollution vulnerability assessment of Coastal Plain Sand Aquifer based on standard and modified DRASTIC approaches, southeastern Nigeria

Two vulnerability index approaches: Standard and a modified DRASTIC, were applied to assess the pollution vulnerability of a coastal plain sand aquifer in parts of southeastern Nigeria. These methods were used to produce vulnerability maps and a groundwater risk map. The results suggest that the aquifer is of moderate vulnerability, while the risk of pollution is high. These maps also identified three vulnerability categories: low, moderate and high. Agreements in the categories of the two methods is found for about 80% of the aquifer area. Generally for this study, 23% of the southern parts of the study area is highly vulnerable and urgent pollution prevention method is necessary. This is due to the high human activity related to oil and gas activities. Comparison of the vulnerability indices with nitrate concentration showed some discrepancies. The study is expected to guide the future development, pollution and management of the aquifer.

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Session Classification : Poster with refreshments

Track Classification : Topic 1 - Groundwater assessment and management
Hydrogeological functioning of an andesitic island revealed by helicopter-borne electromagnetic survey (Martinique – Caribbean island)

Thursday, 26 September 2019 17:15 (15)

Water resources exploration on volcanic islands is challenging as these territories frequently face high population densities with increasing water demands. Improving the hydrogeological knowledge of these islands is thus a major objective in order to achieve a sustainable management of their water resources.

We take advantage of a SkyTEM helicopter-borne geophysical survey over Martinique Island (Lesser Antilles) which allow, overcoming dense vegetation and steep slope constraints, providing information’s on the first 200 m depth. We conducted multidisciplinary studies at different spatial scales on this subduction zone andesitic island. These studies aimed to interpret resistivity data in terms of hydrogeological structures and properties for constraining hydrogeological conceptual models.

We firstly demonstrated, at the aquifer scale, that heterogeneous hydrodynamic properties and channelized flows result from tectonically controlled aquifer compartmentalization along structural directions imaged by resistivity and magnetic maps. Furthermore, we show that the most fractured compartments have lower resistivity and higher transmissivity. Compartmentalization and transmissivity contrasts thus protect the studied coastal aquifer from seawater intrusion.

At the watershed scale, we put in evidence that the main geological structures lead to preferential flow circulations and that hydrogeological and topographical watersheds can differ, influencing river flowrates. Correlation between resistivity, geology and hydraulic conductivity data of four aquifers also reveals that the older the formation, the lower its resistivity and the older the formation, the higher its hydraulic conductivity. Consequently, unlike hot spot basaltic islands, hydraulic conductivity of the studied aquifers, associated to subduction zone andesitic volcanism, show an increase with age. This enhancement of hydraulic conductivity may be the cumulative effect of tectonic fracturing produced by the recurring earthquakes in this subduction zone.

Finally, our approach allows characterizing the properties of aquifer and aquitard units of Martinique, leading to the proposition of hydrogeological conceptual models that suits the complexity of the island at different scale, with heterogeneous geological formations presenting high lateral and vertical variability. Consequently, our result will allow better constraining future exploration drilling campaigns and led to improve management of water resource.

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Session Classification : Parallel

Track Classification : Topic 5.2 - High island hydrogeology
An Intelligent Framework for Groundwater Overexploitation Management (based on hydrogeological modeling)

Monday, 23 September 2019 17:45 (15)

Hydrogeological modeling is an indispensable decision support tool for sustainable groundwater resources management. However, one of the major issues in Groundwater numerical modeling is related to the basic data preparation required for running this open sources or commercial packages models. The experienced user or a newcomer of various existing powerful models such as MODFLOW, FEFLOW, etc, is often lost during the data preparation phase. Hence, one of the main motivations for this work is to develop an expert system able to reproduce heuristics mechanisms of hydrogeologists/experts in order to assist engineers/researchers in the main stages (essentially prior) of hydrogeological modeling (to analyze and study in depth the aquifer system).

A rule based expert system, called ALAES (ALae Aquifer Expert System), dedicated to this purpose, was built adopting object oriented approach, and using an Expert System Shell. It includes: 114 class, 1136 instances, 179 functions, 192 rules and two types of interfaces. This work describes the main steps of ALAES development, its top level object hierarchy, and corresponding heuristics rules. Most of the advice given by ALAES working system was evaluated and validated in the Moroccan Rhis-Nekor aquifer case study. ALAES allows to: i) select the appropriate hydrogeological model depending on the aquifer problem studied and judge its modeling feasibility, ii) prepare the necessary inputs data for Hydrodynamic model, iii) guide the user during the modeling process, and determinate the optimal future water management scenario of groundwater resources.

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Session Classification : Parallel

Track Classification : Topic 1 - Groundwater assessment and management
Is it possible to introduce 3D complex heterogeneities in a real transient groundwater model used to manage a sedimentary aquifer?

Thursday, 26 September 2019 16:00 (60)

Almonte-Marismas aquifer system maintains the biodiversity richness of one of the most sensible wetlands in Spain, which depends on groundwater quantity and quality. Spanish Geological Survey has been studied the aquifer for more than 40 years and plenty of different hydrogeological numerical models have been built. Now, the new challenge is to change the concept of previous homogeneous models and take into account the heterogeneous hydrogeology in order to make an accurate water resources management. The consideration of 3D geostatistical hydrofacies simulation has been the latest improvement of the management mathematical model. The restructuring of the sedimentary system of the Almonte-Marismas aquifer into seven hydrofacies contributed to a more realistic characterization of the hydrogeological properties of each geological unit in the model, leading to a more natural flow pattern. This previous hydrological model, with a detailed description of the units in a 7 layer vertical discretization, was tested in a stationary state framework. The present work wants to go further in the use of this model, integrating this new spatial variable discretization into the transient state. NWT MODFLOW package and UCODE software will be used to automatically interpolate hydrogeological parameters and perform sensitivity analysis. ModelMuse and ModelMate software (USGS) will allow running the mentioned packages to solve the transient groundwater flux related to the complex sedimentary Almonte-Marismas aquifer system.

Keywords: mathematical model, geostatistical simulation, hydrofacies, modflow, transient simulation

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Session Classification: Poster with refreshments

Track Classification: Topic 5.4 - Innovative approaches for understanding groundwater flow systems
THE EPIPHREATIC FLOW IN MATURE KARST AQUIFERS: THEORY, MODELS AND OBSERVATIONS

Thursday, 26 September 2019 15:00 (15)

In many karst aquifers, the epiphreatic flow presents a major contribution to spring’s medium to high flow discharge. The flow follows a system of conduits and channels distributed in the transitional phreatic/vadose zone and shows very complex spatial and dynamic patterns. The flow regime frequently changes in all directions from pressurised to open channel and no flow conditions. Fast and high water level fluctuations are often encountered, particularly in tectonically active and structurally complex settings, such as in young orogens. There, solution conduits evolve in continuously changing boundary and structural conditions and are therefore far from equilibrium with the span of recharge. We present a set of simple hydraulic models to discuss possible flow situations in the epiphreatic zone. Concepts and consequences such as overflow phenomena, back-flooding, flow reversals etc. are presented. These concepts are demonstrated with a set of examples from several karst systems of Slovenian Dinaric karst. There, several long-term monitoring networks have been established in most caves with access to the epiphreatic flow. Caves often provide the only (yet demanding) access to the epiphreatic level, where installed autonomous loggers record physical and chemical parameters of groundwater. The analyses of these records in view of the basic hydraulic principles and known local geometry of the conduits system gives new insights into the dynamics and spatial distribution of flow within the aquifer. Finally, we also give an experience-based set of instructions on how and where to install instruments in caves to get the optimal data on the epiphreatic flow.

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Session Classification : Parallel

Track Classification : Topic 7 - Karst Hydrogeology
The strip of the Depresión Central (Central Depression) in northern Chile, between latitudes 24-25°S, is in the arid core of the Desierto de Atacama (Atacama Desert). This area is characterized by air humidity close to zero, which is the origin of scarce precipitations and consequently very small surface runoff. Despite this, some small springs (more or less permanent seepages) outflow in the western slope of Cordillera de Domeyko (Domeyko Range), to the west of the Depresión Central. This shows up that there is groundwater, which the low parts of the basins is accessed by some mining companies. To understand this groundwater system, a hydrogeochemical model is needed, allowing the identification of the origin of solutes in groundwater. Groundwater salinity varies from medium mineralization to highly saline. The present research is based on the major ions and several isotopes ($^{87}$Sr/$^{86}$Sr, $\delta^{34}$S (SO$_4$), $\delta^{18}$O (SO$_4$)) of groundwater samples. The research has identified a mineral soluble contribution in atmospheric dust originating from salts found in the Depresión Central. The contribution of this dust affects the chemical fingerprint of meteoric water precipitating in the high areas of the Cordillera de Domeyko. The study excludes a marine aerosol contribution to this area. Solute concentration and the ratio Cl/Br have pointed out the significant evapotranspiration processes, discarding halite dissolution. The isotopic variations allow identifying 3 possible geological units involved in water-rock interaction processes. In the central strip of the Cordillera de Domeyko water flows through intensely fractured Permian volcanic rocks, where the chemical fingerprint is close to recharge water, which along the downward flow path leach the eolian salts and dust in the Cordillera de Domeyko slope. There, groundwater acquires the rock radiogenic fingerprint, while the main source of sulphate comes probably from atmospheric dust. Below 3400 m asl, strontium isotopic composition changes, showing a low radiogenic strontium source, probably associated to the marine origin Jurassic carbonates existing in this area, which are easy to dissolve in this environment under favorable conditions. While the isotopic fingerprint of sulphur and oxygen in sulphate point to a probable relationship with kinetic oxidation of sulphides or native sulphur, coming from previous diagenetic processes and that can be associated to the stinking carbonates in this geological unit. Groundwater in the most distal areas of the Cordillera de Domeyko are possibly related to a mixture with salts in the formation Gravas de Atacama (Atacama Gravels) existing in this area. This will support the idea that a local remobilization through the dust entrained by the wind from the Depresión Central to higher elevation areas.

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**Session Classification:** Poster with refreshments
**Track Classification**: Topic 6 - Groundwater, wetlands and natural heritage
Contribution of deicing and rainfall to recharge to a volcanic aquifer in northern Chile

Tuesday, 24 September 2019 16:00 (60)

A study has been done on recharge to a volcanic aquifer in arid climate, in the Andean Altiplano (Highland) in northern Chile. This is important for ecosystems and shallow saline lakes depending on these water systems. In order to consider deicing and rainfall contribution to recharge, an energy balance of the snow cover has been done using the code FSM and a water balance in the soil using the code Visual-BALAN. To calibrate the energy balance the presence of snow has been mapped in the high part of the Tuyajto Volcano, using satellite MODIS / Terra images and the results has been compared with the simulated results, while for the soil water balance data on piezometric level and springs in the northern and eastern boundary of Laguna Tuyajto (Tuyajto Lake). Results show that estimated average recharge is 35 mm/year, which amount to 23% of average annual precipitation. However, average recharge values decrease to 15 mm/year, equivalent to 12% of average annual precipitation, at altitudes below 4700 m, due to the clear reduction of snow precipitation, the higher temperatures and the existence of sediments containing a greater fine fraction in the center of the basins. It has been estimated that the greatest recharge (32%) is produced in March and coincides with the greatest frequency of intense short rains. During this month there is no deicing contribution to recharge as snow precipitation events amount only to a few mm that fully evaporate before ice melt. The second greater recharge month is November (14%) with snowmelt contributing 100% of recharge from the melt of snow that cumulated during the austral winter and did not melted due to the low temperatures. In general terms, ice contribution to recharge is important at elevations higher than 4700 m asl. Recharge exceeds 30% above 4900 m asl and is 13% between 4700 and 4900 m asl. Below 4700 m deicing is irrelevant (<1%) to produce recharge. Deicing contribution to recharge is greater during September, October and November, amounting respectively to 44%, 38% and 100% of total recharge. It has been demonstrated that deicing and rain contribution in a basin in the Altiplano in northern Chile have seasonal variability and that snow play an important role in the water balance of these systems. This is important for sustainability studies of groundwater existence and use.
Aquifer recharge mechanism in the southeastern area of the Salar de Atacama, northern Chile, from the isotopic composition of water.

Friday, 27 September 2019 12:15 (15)

A qualitative study of recharge in the southern part of the Salar de Atacama has been made based on hydrogeochemical and isotopic techniques. Precipitation water samples correspond to the accumulated rainfall in the period 2017-2019. The local meteoric line of precipitation is established from the values of δ18O and δ2H in rainwater of the southern part of the Salar de Atacama, complemented with data from snow samples obtained in June 2017 in the Salar itself. The equation of the local meteoric line is approximately δ2H = 8δ18O + 15 ‰ V-SMOW.

Several field observations in the upper parts of the southeastern basins contributing to the Salar de Atacama show that a large part of their surface is covered by ignimbrite deposits and alluvial and aeolian sediments associated with the weathering of these volcanic rocks. The capacity of ignimbrites to allow significant diffuse recharge is at most very small because a large part of the rainfall that falls on their surface is stored, increasing soil humidity, and is subjected to intense evapotranspiration. Also, the thickness of the alluvial and wind deposits existing in these areas suggests that the field capacity must be quite significant, so recharge process through the soil would be very limited.

The isotopic composition of the water in some lagoons at the boundary with the large salt flat (salar) is particularly interesting when making the isotopic interpretation of δ18O and δ2H to evaluate the recharge. Ephemeral lagoons accumulate water from surface runoff of large sectors of the upper part of the Salar de Atacama southeastern area, where it slowly infiltrates and recharges the aquifer. The isotope composition of water of these lagoons shows isotopic fractionation by evaporation and reaches values that respond quite well with the isotopic composition of groundwater throughout the eastern edge of the Salar de Atacama. This would indicate that the recharge at the eastern edge of the Salar de Atacama is a preferential process, as it happens in many other arid areas of the planet. Thus, it is possible that the recharge that occurs at the southeastern edge of the Salar is only preferential and occurs when important precipitation events are produced, which are capable of generating significant runoff that is temporarily stored in the lagoons.
Environmental Impacts on Groundwater of Wadi Fatimah, Western Saudi Arabia

Thursday, 26 September 2019 16:00 (60)

Abstract
Groundwater resources are precious everywhere for agriculture and human activities, especially in arid regions where no rivers or surface water. Groundwater may be subject to contamination through the natural impact of the quality of the water bearing formation (e.g. long term of aridity or climate change), or by human such as sewage or agricultural activities. Wadi Fatiamh, located in Western Saudi Arabia, is occupied by Pre-cambrian Arabian Shield fractured rocks and Quaternary alluvial deposits. This Wadi is one of the most important groundwater resource for agriculture and drinking in Western Saudi Arabia. This wadi is exposed to pollution as a result of various natural or/and human activities. This study aims to detect the spatial contaminants distribution and the main sources attributed to the concentration of heavy metals in the groundwater of the wadi. The results show that some elements are above the standard and the contamination is not distributed systemically in the study area. In general, groundwater in wadi Fatiamh need treatment and monitoring to be used for different purposes.

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Session Classification : Poster with refreshments
Track Classification : Topic 8 - Groundwater quality and pollution processes
Use of stable isotopes to identify sources of nitrogen transformation processes in the aquifer of the Campo de Montiel (Central Spain)

Thursday, 26 September 2019 11:15 (15)

Human activities affecting continental aquatic ecosystems include intensive agriculture, specially developed throughout the second half of the 20th century. The excess of nitrogen fertilizers applied to agricultural fields is leached into the aquifers causing pollution by nitrates, which is transported in turn towards the discharge areas, affecting surface waters at rivers, lakes and oceans. In addition, nitrogen undergoes various transformation processes, being denitrification one of the most important as it is the main natural process to remove nitrogen in lakes, rivers and wetlands to the atmosphere. High concentrations of nitrates produce different types of stress in the waters, generating different environmental issues and risks to human health. To improve the qualitative status of these surface and groundwater bodies, it is necessary to develop a detailed study of the source, fate and transformation processes nitrogen is undergoing.

This study and characterization of the nitrogen cycle has been developed in the Campo de Montiel aquifer (Central Spain). It was determined that between 11-34% of the fertilizer annually applied is leached into the aquifer, being considered the responsible mechanism for the high concentrations of nitrate in groundwater, higher than the maximum allowed by the legislation. Nitrate dissolved in groundwater is slowly transported to discharge zones and affects the Ruidera lakes, a protected Natural Park, having been estimated exports of 23% of the applied nitrogen. The source of this contamination by nitrates in water can be analysed from the study of $\delta^{15}N$ and $\delta^{18}O$ isotopes of the nitrate, since this relationship varies depending on the pollutant source. It was determined that the main source of nitrate in the aquifer of the Campo de Montiel is the use of nitric fertilizers in agricultural areas. In addition, the isotopic values of $\delta^{18}O$ are closely related to isotopic fractionation processes by denitrification, contributing to the natural attenuation of nitrate in groundwater.

Key words: isotopes: nitrates; groundwater; nitrogen biogeochemistry cycle; contamination
Some unsolved aspects on groundwater to be considered in the revision of the European Water Framework Directive

Monday, 23 September 2019 15:30 (15)

Groundwater is an essential component of the hydrological cycle, which behaves slowly, thus providing long-term water storage and subjected to slow evolution. In practice results can be largely irreversible in the case of large aquifers and thick unsaturated zones. Through the interaction with surface water it is a key component to many ecological systems of relevant social and economic value, but also an important water resource for humans and their activities. Both aspects have to be combined to get the maximum social benefit in the long-term, which means that they cannot be maximized separately from the others.

The European Water Framework Directive of 2000 and the so called Groundwater Daughter Directive of 2006 have as a main objective the good ecological status of the Earth’s water bodies and this has to be accomplished in the so defined water bodies. This may be clear for surface water but is more difficult for groundwater, especially because their environmental role is complex, anthropic effects are highly delayed, and the aquifers may and should play the role of natural infrastructures to increase and guarantee the availability of water resources for humans, especially in droughts. The concepts of water heritage, water resource budget in quantity and quality, and loss of them by passive accumulation from human activities has been rarely made explicit with a long-term perspective.

A revised extension of the Water Framework Directive should consider the role of aquifers as natural manageable infrastructures, whose use may be accompanied by some limited environmental loss when there is a positive social benefit, in the same way that the land can be occupied for urban expansion, transportation or surface water storage in dams. This may be associated with some controlled and managed degree of groundwater level drawdown, wetland reduction, increased cost of groundwater abstraction, water quality changes relative to the natural situation, seawater intrusion in coastal aquifers, land subsidence, water reserves decrease, etc. To consider this, a redefinition of the good status has to be worked out, which is especially needed in the southern areas of Europe.

Other aspect to be considered more in detail is the delayed effect of water transfers, irrigation or land drainage, which may greatly alter aquifer recharge and consequently the full water system. The water system will evolve slowly, often only perceived with good monitoring and adequate interpretation. Large passives of pollutants may cumulate, making recovery unfeasible. So, aquifers need different qualification of the status and protection according to their human water supply, environmental and security role. In these aquifers should be imposed adequate standards of well construction to prevent the entry of pollutants. Some difficult to recover aquifers should have reduced requirements, but considering externalities and how to compensate them.

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Session Classification: Parallel

Track Classification: Topic 1 - Groundwater assessment and management
CONCEPTUAL HYDROGEOLOGICAL MODELS OF OCEANIC INTRAPLATE VOLCANIC SMALL ISLANDS

Thursday, 26 September 2019 17:30 (15)

The origin of oceanic intraplate volcanic islands is attributed to hotspots rising from the lower Earth mantle. They evolve following patterns that are now known from the geological and oceanographic studies of different archipelagos and consist on submarine volcanics topped by subaerial effusions. They form some of the highest Earth’s mountains, up to some thousand metres from the sea bottom to the top. Well-studied Archipelagos, as Hawaii and the Canary Islands, have provided geological models that can be applied to other islands and archipelagos, like Madeira, Cabo Verde, Reunion, Mauricius, Galapagos, Easter or Azores. Each island has its peculiarities, depending on the geodynamic setting, tectonic activity, age and degree of erosion. Groundwater is often the most important water resource, so the understanding of the hydrogeological behavior is the key for good management of water resources. The specific hydrogeological characteristics of the volcanic materials depend on several variables. Lithology is dominantly basaltic in most of the islands in its first stages of growth but differentiation to phonolitic and even rhyolitic materials can occur in late stages. The emplacement mechanisms condition if the piled up rocks consists on lava flows (effusive eruptions) or pyroclastic materials (explosive eruptions). The geological structures, like the existence of calderas, dykes or interlayered sediments determine in great manner groundwater flow. The porosity and/or permeability of the aquifers highly decrease with the age due to compaction and endogenic effects. Several hydrogeological conceptual models have been proposed for different oceanic islands, such as the Hawaiian model and the Canarian model and more recently the models for Galapagos Islands, although not always results are well-supported by observations, hydrodynamics and natural tracers. Some numerical models have been implemented in the coastal areas of Hawaii and the Canary Islands as well for the whole island. Results are scale-dependent. All the conceptual models must consider the variables described above plus the climatology of the islands, which strongly conditions aquifer recharge. This recharge is a difficult to evaluate variable that generally cannot be calibrated due to the unknown, dominant discharge to the sea along the coast. The groundwater behaviour changes with groundwater exploitation. Exploitation has to be known, not only to close the water balance but because the results help in understanding the flow pattern. The hydrogeochemistry and environmental isotope studies can be important tools to define the conceptual model. There are so many variables that influence groundwater behaviour in volcanic intraplate oceanic islands that it is not recommendable to fit the data of a given island to the assumed model of other island or part of it. The real model consists simply in applying the general principles of island genesis and post-depositional effects, with the support of good monitoring data and careful observations.

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Session Classification: Parallel
Track Classification: Topic 5.2 - High island hydrogeology
Assessing the water balance in the high mountain Mediterranean karst aquifer of Ordesa and Monte Perdido (Central Pyrenees)

Monday, 23 September 2019 16:00 (60)

High mountain karst aquifers generate important natural water resources that are used in the low zones to satisfy the demand of both the users depending on this resource and the existing downstream ecosystems. These hydrological systems are highly vulnerable, especially those located in the drought-prone Mediterranean area, where climate change is expected to have a significant negative effect on water availability. Despite of their importance, most of these hydrogeological systems are still vaguely characterized.

The Ordesa and Monte Perdido National Park (PNOMP) is located in the Southern Pyrenees and it constitutes the highest karst system in Western Europe. It is formed by upper Cretaceous and lower Paleocene–Eocene fissured and karstified limestones. The recharge zones are mainly located between 2500 m and 3200 m a.s.l., where snow accumulates and remains almost half of the year. During the spring, snow-melt water infiltrates though the well-developed karst system and recharges the aquifer. Groundwater discharges through a large number of springs that naturally drain the aquifer. This work is twofold: (1) to estimate the terms of a first water mass balance of the Ordesa and Monte Perdido hydrogeological system, highlighting the uncertainties and weaknesses of the estimated terms of the mass balance, and (2) to delineate the conceptual model of the aquifer system behavior.

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Session Classification: Poster with refreshments

Track Classification: Topic 2 - Groundwater and climate change
Emerging compounds monitoring in Santiago Island groundwater: preliminary results

Thursday, 26 September 2019 16:00 (60)

In intraplate oceanic volcanic islands, groundwater is the most important water resource and therefore, to monitor its quality is basic to use them in a sustainable way. Santiago Island, located in Cabo Verde Archipelago is included in the works of the ADAPTaRES project (Adaptation to climate change in Macaronesia through efficiency in water use and reuse). One of the objectives of the project includes the evaluation, optimization and demonstration of reclaimed water in agriculture and promotion of good irrigation practices adapted to climate change and drought. The use of reclaimed water in agriculture is almost an imperative in arid and semiarid climates. The challenge is to use a combination of water quality and irrigation management practices to avoid any negative affection to the aquifer. To assure this challenge, in Santiago Island several wells that exploit the island aquifer and a spring, close to the sewage treatment plants of Santa Catarina and Santa Cruz, have been monitored in June 2017 and January 2019. The same values were obtained in both dates for nitrate (35-50 mg/L in monitored wells and 70 mg/L in the spring) and CE (from 450 to 1200 µS/cm in wells and 720 µS/cm in the spring). Two groundwater points were selected to monitor Nicotine, Caffeine and its metabolite, Paraxantine, and 8 pharmaceutical products. In the selected well near Sta Cruz’s ETAR, the emerging pollutants analyzed (except for caffeine) are not detected. In Santa Catarina’s spring, besides Caffeine and its metabolite, two anti-inflammatories have been detected. As in Gran Canaria previous studies, the highest emerging compounds values obtained in groundwater coincided with higher EC and nitrate contents. In this sense, the aquifer can integrate nitrate from septic tanks, irrigation return flows and sewage systems leakages, which are also sources of organic contaminants. More studies are necessary to understand the Santiago Island aquifer behaviour.

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Session Classification : Poster with refreshments

Track Classification : Topic 5.2 - High island hydrogeology
Identification of flowpath and depict of flow system of deep buried karst system (Jinci karst catchment) in northern China

Thursday, 26 September 2019 12:30 (15)

Karst Water play an important role for water supply worldwide, especially in the carbonate areas. Jinci karst spring is one of the most famous scene spots in northern China, with c.a. 3500 year’s history. In this study, hydrogeochemical stable isotopes and geochemical modeling were employed to identify the major flowpath and to depict the flow system of this deep buried karst system. Two major flow path were identified successfully and the flow system was depicted with some major modification on the basis of old version. The karst water from the west deep buried area is estimated to contribute about 25-30% water supply for the The main runoff belt along the fault.

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Session Classification : Parallel

Track Classification : Topic 7 - Karst Hydrogeology
A practical approach used to plan and execute, quantify and qualify an effective well clean-up strategy

Friday, 27 September 2019 12:00 (15)

The Water Corporation of Western Australia has historically spent several hundreds of hours per deep well, performing clean-up operations. Bringing a new well on-line is an expensive proposition and the need to ensure optimal performance is critical. This case study presents a practical approach using new technologies, workflows & methods that reduced production impairment and verified success which were conducted on a large multi-well MAR project in Perth, Western Australia.

The practical approach used:
• A Novel Drilling fluid designed to protect near-well bore and stress-cage the well.
• Design of an acid soluble drilling fluid system which could be broken down and pumped out during well development; and
• Development of acceptance criteria to verify a clean well. The comparison of flow logging and cumulative BMR derived transmissivity allows:
  1. Verify synthetic flow log against actual, therefore quantifying clean up performance metrics.
  2. Identification of impaired production zones for further targeted clean-up where deviation of two sets of the data occurs.

This case study demonstrates the successful implementation of an integrated approach to well clean-up using several scales of permeability data from core to wireline BMR to well test. This case study demonstrates that, in this particular setting, the use of the presented methodology was cost effective, yielded positive confirmation of asset delivery, and has led to a 90% reduction in clean-up associated time.

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Session Classification : Parallel

Track Classification : Topic 1 - Groundwater assessment and management
How to account for uncertainty in estimation of adsorption isotherms parameters?

Tuesday, 24 September 2019 16:00 (60)

Adsorption parameters used in the modeling of reactive solute transport are usually inferred from laboratory tests such as batch adsorption tests. Experimental data of adsorbed solute, S, and equilibrium concentration, Ce, are measured and then used to infer coefficients that control the adsorption through adsorption isotherm models using fitting techniques. However, as a result of the high costs of chemical analysis and the complexity of the experimental setup, the number of batch tests is usually small and also the observed data is subject to measurement error. Because of that, the fitting of the experimental data to the adsorption isotherm models is never exact, and it can be even worse when the number of samples is small. In this research, we use the normal-score ensemble Kalman filter method to estimate the adsorption parameters, instead of using the standard fitting techniques. Our objective is to quantify the uncertainty in estimation of adsorption isotherms parameters assessing how prior uncertainty is reduced as new samples are collected and also how the final uncertainty is affected by the magnitude of the measurement errors. The method is applied to synthetic examples of non-linear isotherm parameter inference. Langmuir sorption coefficient, k1, and Freundlich sorption coefficient, b1, will be derived from S and Ce, assuming non-linear adsorption models. At the end we compare our method for parameter estimates with the current practice in which the uncertainty is not accounted for.

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Session Classification : Poster with refreshments

Track Classification : Topic 5 - Tools, methods and models to study groundwater
Recharge evaluation is a key element to define the hydrogeological behavior of an aquifer. In volcanic oceanic islands, where groundwater is often the most important water resource, the knowledge of recharge areas and mechanisms and its quantification is of paramount importance. Different methodologies can by applied for the evaluation, as the daily soil water budget (SWB) or the atmospheric bulk chloride deposition mass balance (CMB). But not easy to obtain data are often not available and this led often to considerable result uncertainty, which has to be also estimated. Uncertainty has to be taken into account, as recharge strongly conditions management decisions.

Among the works done inside the REDESAC Project, the average diffuse groundwater recharge in northeastern Gran Canaria Island was calculated for the 2008-2014 period. This is the area where the largest recharge to the island volcanic aquifer occurs. No permanent surface runoff exists on and it happens sporadically associated with short, heavy storms. In the study area, runoff was calculated by applying the USCS curve-number method for the 1980-2014 period, using a geographical information system that allowed the discretization of the area according to slope, soil use and soil typology. Average storm runoff was estimated to be 12 hm3/year or 9% of precipitation. The CMB is the most widely used tracer technique to estimate long-term groundwater recharge under steady-state conditions. It was applied in the study area. Rainwater was sampled monthly in ten rainwater collectors located close to rainwater stations. Groundwater chloride concentration was determined from selected wells with low nitrate contents to avoid chloride contribution from irrigation returns as well as the chloride contents in runoff water. The average total recharge volume in the considered area was estimated to be about 28 hm3/year (92 mm/year), which is almost 24% of precipitation. The spatial recharge is variable, from 3% of precipitations in the eastern coast, up to 27% of precipitations in the middle-high northeastern area. At the same time, a daily water balance in the soil was performed, dividing the area into subzones according to the situation of the rainfall stations and the climatic characteristics. Calculations were made using the Easy-Bal code to yield a recharge of about 15±4 hm3/year, or 13±4% of precipitation, most of it concentrated in the high and medium altitude areas. The difference between the results of the two methodologies is not surprising because it was not possible to calibrate the daily soil water balance using water table fluctuations or discharge measurements, as these data are not available and the CMB method needs more sampling time to reduce uncertainty, among other considerations.
Track Classification: Topic 5.2 - High island hydrogeology
New Quickscan method for prevention of groundwater pollution through stormwater infiltration, XRF as new quick scan method to map heavy metals in Dutch Sustainable urban Drainage Systems

Friday, 27 September 2019 11:30 (15)

Sustainable Urban Drainages Systems (SuDS) are designed to collect, store and infiltrate large amount of surface runoff water during heavy rainfall. Surface runoff water is known to transport pollutants such as particle bound heavy metals. Therefore, a build-up of pollutants in the top-soil, of the commonly vegetated filter media is expected in SuDS such as swales.

In the Netherlands the first large scale implementation of swales in a residential area was finished 20 years ago, followed by many municipalities. In 2019 more than 500 locations with swales can be found throughout The Netherlands (www.climatescan.nl). Questions are raised by water authorities, provinces and municipalities how efficient swales are in capturing pollutants from stormwater and if pollution of groundwater can be expected threatening the quality of our drinking water. Previous studies show concerns on heavy metals in stormwater. Knowledge of heavy metal concentration in the top soil is therefore very important for assessing the purity and quality of the soil in an environment and effect on the groundwater. The concentrations of heavy metals from 30 Dutch swales older than 10 years were measured and analysed using a portable X-ray Fluorescence (XRF) spectroscopy instrument verified with soil samples analysed in laboratories with the ICP-MS and XRF methods.

This study developed a new methodology for quick scan in-situ mapping of pollutants in the top soil of SuDS. This method is time and cost efficient, easy to execute and is sufficiently precise to qualify for any known international or national threshold criteria for polluted soils. It makes time-consuming and costly interim analyses by laboratories superfluous and makes it possible to adapt monitoring schemes in the field to more detail when high concentrations are found or prevent unnecessary analyses in unpolluted areas.

The research results show that in 1 out of 5 swales older than 10 years have heavy metal concentrations higher than threshold values. The high concentrations are mostly found near inlets of the stormwater. The results of study are shared in 2 national workshops and valued as of great importance for all stakeholders in (inter)national cities that are involved in implementation of SuDS for climate adaptation. The Dutch research results will be used to update (inter-)national guidelines for design, construction and maintenance of infiltration facilities this year. Stormwater managers are strongly advised to use this quick scan method within the first 10 years after implementation of swales to map possible pollution of the top soil and prevent pollution to spread to the groundwater in urban areas.

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Session Classification: Parallel

Track Classification: Topic 8 - Groundwater quality and pollution processes
Numerical and analytical assessment of stormwater infiltration via wells and infiltration trenches

Numerical and analytical assessment of stormwater infiltration via wells and infiltration trenches

Tuesday, 24 September 2019 11:45 (15)

Arid and semi-arid regions, also referred to as drylands, are areas characterised by low water availability. A solution commonly used in drylands to cope with water scarcity is the collection of stormwater, which is stored during wet seasons or rain events and subsequently used during drier periods. Storage is often provided by infiltration into shallow aquifers. Common problems with the storage of stormwater in surface water bodies or during infiltration phases are high evaporation rates, salinisation, mosquito-breeding potential, among others. These problems are majorly a consequence of too low infiltration rates, which is caused by clogging layers in the topsoil and the presence of a thick vadose zone over the underlying aquifer. This study aims to increase the groundwater recharge rates in stormwater harvesting systems by bridging the vadose zone and the low permeable upper layers of the soil profile. We explored the efficiency of vertical structures that allow high infiltration rates by means of analytical and numerical models. Two structures are studied in detail, namely shafts and infiltration trenches. We assessed the validity of the numerical scenarios and the infiltration structures modelled using analytical models. Due to the variety of hydrogeological conditions and stormwater harvesting systems that can be found in drylands, we focused on the Kingdom of Saudi Arabia and the dams built in the channel of wadis (i.e. ephemeral streams) as a study case to construct the numerical scenarios. The results of the modelling scenarios suggest that the shafts and infiltration trenches are effective in bridging the upper layers of a typical soil profile in a wadi dam. By using such structures, recharge was significantly enhanced in comparison with the scenarios at which stormwater infiltrates directly through the vadose zone in a wadi dam. We also carried out a sensitivity analysis of key hydraulic and infiltration-structure parameters. Therefore, the results of this study have applicability beyond the Kingdom of Saudi Arabia as similar hydrogeological conditions related to wadis can be found in other parts of the world such as northern Africa, southeastern Asia and the southwestern USA. Furthermore, dams are presently used in other dryland countries as the main structure for groundwater recharge; the methods investigated here to increase infiltration rates, therefore, provide meaningful options to enhance aquifer water storage.

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Session Classification : Parallel
Track Classification: Topic 2 - Groundwater and climate change
New ‘full scale’ monitoring method for (subsurface) stormwater infiltration to protect groundwater, long term (hydraulic) efficiency of SuDS in The Netherlands

Friday, 27 September 2019 10:25 (15)

Management of sustainable urban drainage systems (SuDS) for retention and infiltration is an example of an approach that complies with climate adaptation. Next to the implementation of surface infiltration facilities (swales), in the densely populated Dutch cities most infiltration facilities are sited under roads and pavements located in or just above the groundwater level. Compared to infiltration at surface level, the environmental risks of subsurface infiltration are presumed to be higher because of anaerobic conditions in the surrounding soil. Although subsurface infiltration systems are widespread in The Netherlands (www.climatescan.nl), little knowledge is available about their long-term hydraulic and environmental performance, maintenance requirements and expected life span.

The hydraulic performance of several types of SuDS has been monitored in over 100 Dutch locations using a new full-scale method where SuDS such as swales, subsurface infiltration facilities, permeable pavement and watersquares are fully submerged to determine the (loss of) infiltration capacity. Most of the swales meet the hydraulic guideline of emptying their storage volume within 48 hours even in the low-lying parts of the Netherlands (below sea level with high groundwater tables and low permeable soil). Loss in infiltration capacity due to clogging is found at some locations with permeable pavement that are in need of cost effective maintenance.

In some cases, additional environmental monitoring related to groundwater quality is executed mapping accumulation of pollutants around infiltration facilities. In seven specific locations the hydraulic and environmental performance have been monitored over a period of ten to thirteen years with different subsurface constructions and different geo-hydrological conditions. Specific attention was paid to environmental risks due to micro pollutants, heavy metals and polycyclic aromatic hydrocarbons (PAHs) in the infiltrated storm water. Samples of the soil and groundwater were taken and analyzed at sequential distances around the infiltration devices. Also new cost effective quickscan method using XRF is applied on swales to study the long term efficiency. After many years of data collection, conclusions have been drawn leading to recommendations for design, construction and maintenance.

Overall, it can be concluded that at all sites investigated (with a single exception) there is no ecological or health risk to the local population. Despite the high groundwater levels most heavy metals seem to have been bound within the first 0.5 meter below the infiltration system. At all research locations the vast majority of concentrations are below reference values. There is therefore an acceptable risk to the environment and human health.

This means that subsurface infiltration with relatively high groundwater levels is possible, and the useful life span of these constructions could be compared to those of normal drainage systems.

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Session Classification: Parallel

Track Classification: Topic 8 - Groundwater quality and pollution processes
Knowledge exchange on Climate Adaptation with Nature-based solutions and Best Management Practices for Sustainable (ground)water management in Resilient Cities

Tuesday, 24 September 2019 15:45 (15)

Cities are becoming increasingly vulnerable to climate change, and there is an urgent need for climateproof resilient cities. Groundwater issues are not always visual to stakeholders so raising awareness and capacity building is of great importance. The Climatescan adaptation tool www.climatescan.nl is applied as an interactive tool for knowledge exchange and raising awareness on Nature-Bases Solutions (NBS) targeting young professionals in ClimateCafes. Climatescan is a citizen science tool created through ‘learning by doing’, which is interactive, open source, and provide more detailed information on Best Management Practices (BMPs) as: exact location, website links, free photo and film material. Groundwater related BMPs such as stormwater infiltration by swales, raingardens, subsurface infiltration in Sponge cities are mapped and published on social media.

Climatescan is in continuous development as more data is uploaded by over 250 people around the world, and improvements are made to respond to feedback from users. In an early stage of the international knowledge exchange tool Climatescan, the tool was evaluated by semi-structured interviews in the Climatescan community with the following result: stakeholders demand tools that are interactive, open source, and provide more detailed information (location, free photo and film material).

In 2016 Climatescan was turned into an APP and within two years the tool had over 10,000 users and more than 3,000 international projects. More than 60% of the users are younger than 34 and 51% of users are female, resulting in engagement with an important target group: young professionals. The tool is applied in Climatecafe.nl around the world (The Netherlands, Sweden, Philippines, Indonesia, South Africa) and other water challenges with young professionals such as the Hanseatic Water City Challenge and Wetskills.

Recently a ClimateCafe was arranged in Malmö, Sweden, where the web-tool played a central part in knowledge exchange and in-field education on climate adaptation linked to WaterJPI funded projects INXCES and MUFFIN. In this event research was connected to the UNSDGs bringing awareness to the Sustainable Development Goals linked to (ground)water. To illustrate the power of the web-tool and the ClimateCafe surveys related to NBS and the UN SDGs were conducted before and after the event, and results will be presented at IAH.

In conclusion, there is a clear demand for a collaborative knowledge-sharing tool on (ground)water, where first impressions of different urban resilience projects can be quickly gained and examples of climate adaptation is easily accessible. Further work in linking events to the UN Sustainable Development Goals will further empower the usability of this web-tool www.Climatescan.nl. This tool helps policy makers and practitioners to gather valuable data for decision-makers in a rapid appraisal at neighbourhood and city level. The results provide insights, create awareness, and builds capacity with bringing together stakeholders in the Climatescan community.

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**Session Classification:** Parallel

**Track Classification:** Topic 10 - Urban groundwater
Are they different volcanic island hydrogeological conceptual models?

Thursday, 26 September 2019 17:45 (15)

The often called “Hawaian” and the “Canarian” hydrogeological behavior of volcanic islands, do not respond to two different conceptual models but one, based on hydrodynamics, climate and volcanic edifice genesis. There is a wide range of possibilities according to structure, age, state of erosion, and precipitation, but responding to the same hydrogeological principles. The hydrogeological conceptual model of single hot-spot intraplate volcano is the combination of a low permeability core, a more permeable cover and a transmissive apron around. These parts may be from sharply separated to a gradual and fluctuating transition. The core holds the compacted old volcanics, the dike zones and sometimes the upper part of the magmatic chamber and ocean floor. These materials are usually thermally and hydrothermally altered. This is a common feature, even if not visible when it is covered by recent volcanics and soils. The core may hold large collapse calderas, later filled by intra-caldera volcanics and erosion materials, plus the corresponding extra-caldera cover. This fill may constitute a high elevation aquifer if closed around or be reduced to a recharge area if open by large landslides or deep erosion. The cover receives the high altitude recharge and groundwater flows to the periphery. Depending on permeability, recharge and thickness, springs and streams appear. The water table may be shallow or up to several hundred meters. The apron, continuous or not, may be narrow or extensive. Water table aquifers are commonly found in it. In the lowest parts semi-confining and even flowing conditions may appear when fine sediments are deposited. This is for a single main volcano under ideal conditions. Reality is more complex as there may be more than one main volcano, separated or partially overlapping, with a wide spectrum of different cumulative structures, state of erosion, and very diverse climate conditions. Attending to local conditions, very different hydrogeological conceptual models can be proposed, often with great uncertainties due to lack of data. The alternative is just applying judiciously the concept of core, cover and apron, focusing on hydrodynamics, and adapting it to the local circumstances and observations. This approach makes easier the formulation of local hydrogeological conceptual models. In the case of rift islands, the above presented approach seems to holds. Andesitic islands in subduction zones are less known, but knowledge can be derived from large volcanoes in continental location. The core, cover and apron concept seem to explain observations, especially in the mountain-front situation of volcanoes and the filled up graven-like large asymmetrical calderas at the side. A possible main difference with respect basaltic volcanism is the important role of thick and extensive ignimbrite deposits, both in intra- and extra-caldera positions.

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Session Classification : Parallel

Track Classification : Topic 5.2 - High island hydrogeology
Detail investigation of environmental effect by leachate for around livestock burial

Tuesday, 24 September 2019 16:00 (60)

Since purifying groundwater is very difficult after it already contaminated, efforts for management and preservation are highly demanded. In KOREA, Recently, Several problems about soil and groundwater have been brought up with management of livestock burial made from avian influenza(AI) and foot-and-mouth disease in 2010~2015. In accordance with relevant laws and regulations, monitoring wells are installed and water quality of the wells is measured periodically. The burials of livestock are sorted as a 3 grade according to result of the water quality analysis for the wells and some of them were under the detail investigation. In this detail investigation, a livestock burials in Neung-gugli, Korea is selected as target area which received water quality grade 1(Bad) and which is suspected of being leaked. Leakage is verified by soil analysis and clostridium perfringens(Maximum 110CFU/g) are detected. In groundwater quality analysis, high concentration of ammonia nitrogen(Maximum 1,136mg/L) is detected. In case of malodor investigation, concentration of ammonia and methyl sulfide gas from gas extracting pipe in the burial exceed Korean standards(Ammonia: 1.03ppm, C2H6S: 3.08ppm). As the result of Detail investigation, it is expected that leachate spread continuously to south direction of livestock burials in neung-gugli. But since the spreading range of leachate is used as non-agricultural land, it is considered that urgent measures are not necessary to prevent spread of leachate. Instead, installing and operating wells for water pumping after destroying the burial is expected more efficient.

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Session Classification : Poster with refreshments
Track Classification : Topic 8 - Groundwater quality and pollution processes
Different responses of groundwater levels in Doñana aquifer through time series clustering

Tuesday, 24 September 2019 16:00 (60)

In recent years, time series clustering is increasingly being applied in hydrogeology. Groundwater level fluctuations in long time series provide essential information to identify different hydrological behaviors and to validate the conceptual model of groundwater flow in aquifer systems. Piezometers also register the response to any changes that directly affect the amount of available groundwater resources.

On February 2019, the Guadalquivir Hydrographic Confederation (CHG) initiated the process to declare overexploited three of the five groundwater bodies of Almonte-Marismas aquifer, which host Doñana area. This new framework highlights the importance of studying historical groundwater level dynamics when defining new water resources management plans. In this work, groundwater level time series from 522 piezometers in the period 1975-2016 were analyzed. Data were preprocessed and transformed: selection of points, missing data imputation and data standardization. Cluster analysis was then applied to classify groundwater level hydrographs using available time series. Different groundwater levels fluctuations and responses were detected associated with the spatial distribution of geological properties in the aquifer. Moreover, actual hydrodynamics of the aquifer system were characterized making it easier for groundwater managers to make sustainable decisions.

Keywords: time series clustering, groundwater levels, hydrographs, water resources management.

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Session Classification: Poster with refreshments

Track Classification: Topic 5 - Tools, methods and models to study groundwater
Maximum-flux constraint for the MODFLOW DRAIN package to simulate dewatering wells

Tuesday, 24 September 2019 16:00 (60)

In dewatering design studies, wells are often implemented as head-dependent (Cauchy-type) boundary conditions in numerical models to obtain a discharge given a targeted drawdown in the excavation site. In the MODFLOW groundwater modelling code, this is often done through the use of the DRAIN package. This has the drawback, however, that initial abstraction rates can be higher than what can be supplied by the physical well. This results in simulated dewatering durations that are often too optimistic in addition to cumulative extracted volumes that are larger than those supplied by the well. A solution to this was found by adjusting the source code of the DRAIN package to allow the user to specify a maximum allowed discharge for the MODFLOW drains. If, during a time step, the simulated drain discharge is larger than the user-specified maximum discharge; the simulated value is limited to this maximum and the drain discharge reverts to a constant-flux (Neumann) type boundary condition independent of the hydraulic head in the cell. The effectiveness of the tool was demonstrated in a dewatering case-study in Belgium where simulated abstractions differed significantly between the adjusted DRAIN package and the traditional DRAIN package.

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Session Classification : Poster with refreshments

Track Classification : Topic 5 - Tools, methods and models to study groundwater
A depth-discrete sentry well network for monitoring water quality impacts to a municipal supply aquifer

The City of Guelph, Ontario, Canada relies on 21 groundwater wells to supply water from an underlying fractured dolostone aquifer to ~135,000 residents. Following the implementation of the Clean Water Act (2006), Ontario municipalities are required to evaluate threats to source water. The approach requires developing wellhead protection areas based on groundwater travel times, which can be complex to estimate in urban environments with variability in infrastructure, land use, and recharge. The variety and age of potential contamination source zones, following decades of urban and industrial activities, provides impetus to assess aquifer vulnerability by utilizing the best-available characterization and monitoring techniques.

This study involves a municipal supply well and surrounding aquifer system, where trace concentrations of trichloroethylene (TCE) have been detected since the mid-1990s. In collaboration with the City of Guelph and their consultants, a 3-D sentry monitoring network was designed surrounding the municipal supply well to monitor variable hydraulic and contaminant conditions for early assessment of trends in water quality at multiple depths and directions within the capture zone. Four boreholes were drilled radially around the supply well (3 km² area, ~70 m deep), intersecting flow paths between the well and suspected sources. Of the four boreholes, one ‘golden spike’ location was selected as a method calibration borehole where a suite of high-resolution geophysical and hydrophysical datasets were collected, including VOC analysis of rock core samples, following the discrete fracture network–matrix field approach (Parker et al. 2012).

Robust golden spike data, including continuous core logging and transmissivity profiles, informed the placement of 7-10 depth-discrete ports in each multilevel system (MLS), forming a 3-D monitoring network. Ports targeted zones with active groundwater flow, rock core VOC detections, and aquitard layers, while minimizing the cross-connection of distinct hydrogeologic units. MLS design incorporated variable tube diameters to accommodate ports with different functions, and a dedicated fiber-optic cable for monitoring flux variability in the back-filled system.

MLS hydraulic head profiles show the presence of strong downward vertical gradients, induced by pumping, surrounding the supply well. This indicates the presence of an aquitard unit separating two zones of relatively high hydraulic conductivity and, most importantly, two aquifer units with distinct recharge and possible contaminant input areas and residence times.

At municipal supply wells impacted by aged chlorinated solvent plumes, sentry monitoring is a valuable approach to understand 3-D spatial and temporal variability in flow and contaminant distributions, allowing for timely and cost-effective decision-making for supplying safe water to the community. The improved understanding of subsurface heterogeneity and flow conditions around the supply well will be used to update the groundwater flow model, evaluate future risks to water resources and improve strategies for long-term urban aquifer management.

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Session Classification: Poster with refreshments

Track Classification: Topic 10 - Urban groundwater
Modelling groundwater flow and transport contaminant require heterogeneous parameters such as hydraulic conductivity, dispersivity and porosity which commonly are only sparsely available, if at all. State variables such as hydraulic head and concentration are generally more extensively sampled and can be assimilated to improve the characterization of the parameters. In the last decades, many works have focused on the characterization of hydraulic conductivity heterogeneity by assimilating piezometric heads using variations of the ensemble Kalman filter (EnKF). More recently, several authors have worked on the assimilation of concentrations to identify contamination source, aquifer geometry and K. The characterization of the variability of dispersivity and porosity, however, has not been addressed. In this work, the objective is to investigate the capability of the restart EnKF (r-EnKF) to identify hydraulic conductivities, dispersivities and porosities by simultaneously assimilating concentration and water table data in a two-dimensional numerical experiment of an aquifer vertical cross section. Reference data of hydraulic conductivity, dispersivity and porosity are generated. Groundwater flow and transport equations are solved using these reference data. The concentration and the water table obtained from the numerical model are used as the reference aquifer response. Values of the state variables of the reference aquifer are sampled at a limited number of points to serve as assimilating data for the inverse problem. Prior variograms functions of the hydraulic conductivity, dispersivity and porosity are assumed and three hundred equally-likely realizations, conditioned to data from reference aquifer, are generated. Stochastic inverse modelling is conducted using the r-EnKF for the identification of hydraulic conductivity, dispersivity and porosity. The results are analyzed by using the average absolute bias (AAB) that represents a measure of accuracy between the reference values and the realization values. Our results show the importance of the concentration and water table data for improving the characterization of hydraulic conductivity, dispersivity and porosity.
Impact of climate changes on groundwater resources: Study case of N’fis watershed in Marrakech Area, Morrocco

Tuesday, 24 September 2019 15:00 (15)

The N’fis basin located in Tensift region center of Morocco characterized by semi-arid climate, with an area of 2,855 km², in which 60% exceeds an altitude of 1500m. Water resources and exactly groundwater resources were overexploited in N’fis basin and agriculture sector is the most consummate. Water is the key element of socio-economic development. Analysis of the spatial and temporal variations of hydro-climatic series and their trends shows that during the study period (1960-2010) rainfall series, flows and piezometric levels have a downward trend. While temperatures are on an upward trend. And dry years in recent decades are more frequent than wet years.

The piezometric level data were subjected to trend (Mann-Kendall), homogeneity (Pettitt rupture test) and linear regression tests. Significant trends were observed. Taking into account the α value of 5% for the N’Fis 3849/53 piezometer (p < 0.0001), -22.96% for Agafay 3595/53 (p < 0.0001) -6.38% for Tamaslohet 2715/53 (p < 0.0001). 18.42% and for Guemassa 3834/53 (p < 0.0001) 11.38%. On the other hand, the statistical breaks observed for the piezometric levels Agafay, N’Fis, Tamaslohet and Guemassa, (respectively in 2009, 2009, 2006 and 2007) were not all identified in the rainfall series. This means that the evolution of groundwater level in the aquifer also depends on factors other than precipitation.

The present study has as a purpose to study and to determine the exact effect of extreme hydrologic situations (drought and floods) on the piezometric level of the aquifer of N’fis- Haouz takes into account the other parameters mainly the water exploration for socio-economic issues. The study concerns the 30 last years.

Key words: Groundwater, Climate change impact, Statistical test.

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Session Classification : Parallel

Track Classification : Topic 2 - Groundwater and climate change
Pollution of arsenic in groundwater is a major problem in aquifers of Ganga delta in West Bengal, India. Consequently arsenicosis disease is one of the vital issues of public health in this region. In this aspect, determination of the spatial distribution of vulnerable zones for arsenic pollution in groundwater is essential to provide a better public health condition. Detailed study of concentration of arsenic in groundwater is studied spatially to get the hot-spot of such arsenic pollution in Malda district of West Bengal, India. Thematic maps of geomorphology, land-use, palaeo-channels and lithology are studied in details. Spatial correlation of these thematic parameters and distribution of hot-spots of arsenic pollution reveals close association of arsenicosis with newer and recent alluviums in such region. It is further influenced by presence of palae-channel to the proximity of newer alluviums. The study indicates the close spatial correlation of arsenicosis with the newer alluvium and palaeo-channels in the Ganga delta region of West Bengal, India. Such regions in the whole Ganga delta may be considered as the vulnerable zone to arsenicosis. These zones are susceptible to public health condition and close comprehensive monitoring of groundwater quality might provide better public health condition in Ganga deltaic region.

Keywords: Data processing, Data assimilation, Hydrogeology, Remote Sensing, Geographical Information Science & Systems, Geomorphology, Medical Geology.

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Session Classification: Parallel

Track Classification: Topic 8 - Groundwater quality and pollution processes
Hidden figures: What the JMP data do not tell us about groundwater use in urban Sub-Saharan Africa

Monday, 23 September 2019 17:15 (15)

Sub-Saharan Africa (SSA) is undergoing rapid urbanization and dependence on groundwater is expected to increase, especially for the urban poor. Accurate quantification of groundwater use is necessary to develop measures to protect and enhance the resource. The current scheme of global water access monitoring, done by the Joint-Monitoring Programme (JMP), neglects groundwater use when offered as piped water and also neglects self-supply of groundwater when in use as a secondary source. The present study aims to quantify urban groundwater use for Uganda and compare it with JMP national data. A method will be developed to estimate urban groundwater use through Geographic Information Systems by coupling the spatially distributed urban water cycle, urban structure analysis, and high resolution population density. The calculated groundwater use is expected to show that current JMP data underestimates the proportion of population using groundwater. The method developed in this research will be applicable to other cities in the SSA region, and provides a tool for further understanding groundwater dependence and supports evidence-based groundwater management measures.

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Session Classification : Parallel

Track Classification : Topic 10 - Urban groundwater
Managing the Response to Clean Air and Carbon Reduction Targets from Open Loop Ground Source Heat Pump Systems on Urban Groundwater Resources; Two Case Studies

Monday, 23 September 2019 17:30 (15)

In September 2018, the Greater London Assembly published; Low Carbon Heat: Heat Pumps in London. This report states that, to meet carbon reduction and air quality targets there needs to be a significant uptake in heat pumps in the next 10-15 years. Based on estimates of market share (Abesser, 2010), around 1,000 of the 1 million heat pumps sold in the EU in 2016 were Open Loop Ground Source Heat Pumps (GSHP). In 2017 heat pump sales grew 13%, the third consecutive year of growth (EPHA, 2017). Subsequent pressure on urban groundwater resources is expected to continue to rise with the proliferation of Open Loop GSHP systems.

In England the Environment Agency (EA) regulates Open Loop GSHP by Abstraction Licence and Environmental (discharge) Permits. Since the first Open Loop GSHP in 2000, London has 44 licensed systems. In this time, the EA have noted raised groundwater temperatures potentially reducing GSHP efficiency (EA, 2018). Stakeholder’s agreed that thermal impacts of GSHP systems should be increasingly considered by the EA, particularly thermal interference. The EA responded with a Legislation and Policy document (EA, 2008) and an Environmental Good Practice Guide (undated) advocating a risk-based approach. Based on experience, the author considers this to be broadly successful in managing groundwater levels in the Chalk Aquifer of the London Basin, corroborated by the Annual Groundwater Status Report (EA). However, regulatory focus on protecting groundwater levels do not guarantee abstraction volumes or temperatures. In that sense, it is the applicant’s responsibility to assess if the proposed GSHP will be sustainable or impact other systems (Fry, 2009). Local best practice for hydrogeological input into the design Open Loop GSHP systems is discussed in this context; undertaking Environmental Impact Assessment using numerical coupled groundwater flow and heat transport modelling.

In Christchurch, New Zealand the rapid uptake of Open Loop GSHP occurred in response to the 2011 earthquakes and with incentives including streamlined planning and funding grants (Seward et. al. 2017). Up to 20 systems are operational or planned in Central Christchurch, the majority being installed since 2012 (Rekker, 2017). The local regulator (Environment Canterbury) commissioned a groundwater model to investigate anecdotal reports of water table mounding in the city (Rekker, 2017). Groundwater modelling results and anecdotal evidence of groundwater flooding, reactivation of historical springs and problematic recharge pressures will be reviewed in the context of the local regulatory requirements. Christchurch’s layered confined aquifer system mitigates the potential for thermal interference, however, lessons learnt from the regulatory and design perspective will be discussed and presented in this context; demonstrating the absence of regulatory mechanisms to assess individual and cumulative hydraulic impacts of open loop GSHP systems may have led to undesirable outcomes for the City of Christchurch.

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Session Classification: Parallel
Track Classification: Topic 10 - Urban groundwater
Numerical Modelling of Groundwater Flow in Medipalli open cast mine area, Telangana, India.

Monday, 23 September 2019 17:15 (15)

Sustainable groundwater management is a worldwide challenge. Numerical modelling is one such tool which addresses this challenge. Regional-scale modelling of groundwater flow is necessary for planning and management of groundwater resources. The aim of the study is to numerically model the groundwater flow in Medapalli Open cast block area. Medapalli Open Cast Block is a coal mine operating under Singareni Collieries Company Limited SCCL in Telangana, India. It is spread across and lies near river Godavari. The observation well locations and depth to water level data are collected from SCCL. A finite-difference based groundwater flow model is developed in Visual MODFLOW using MODFLOW-2005 code with forty conceptual layers and with a total thickness of 240 m. The model is constructed based on the geological and spatial data of the study area. The model calibration is performed at steady state conditions through trial and error method. In addition to this, a solute transport model is developed using MT3DMS code at steady state conditions. The results indicate that the computed water table values fairly match the observed water table values and the simulated flow direction is towards the river Godavari, in accordance with the field conditions and following the general topography of the region. The solute, i.e. (TDS) migration extends up to a maximum distance of 168 m along the periphery of Medapalli open cast block towards the river. The study shows that the impact of fly ash deposition in Medapalli Open cast mine on the groundwater quality in the vicinity of the open pit will be very less and no harmful effects will be observed as the contaminant levels decrease steeply along the periphery of the mine and concentration of the plume is reduced sharply.

Keywords: Groundwater flow Model, Visual MODFLOW, Medapalli Open Cast block, solute transport, Numerical Modelling

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Session Classification : Parallel
Track Classification : Topic 5.3 - Advanced modelling tools for subsurface hydrology: from the vadose zone to deep environments
Strategies for Sustainable Groundwater Management Plan for Typical Granitic Watershed, Telangana state, India

For sustainable groundwater management plan (SGMP), a study has been taken up in Madharam watershed (95 km²) in drought prone affected mahabubnagar district of Telangana state, India with integrated approach including remote sensing, hydro-meteorological, hydrological, hydrogeological, geophysical and hydro-chemical studies. Geologically the watershed is underlain by granites with intrusive dykes (hard rocks) and characterized by semi-arid conditions with annual normal rainfall of 618 mm. Remarkable changes in land use pattern, have led to substantial impact on the groundwater recharge to the aquifers as ~97% of irrigation is based on groundwater. The productive phreatic aquifer due to high density of wells (14 wells/km²) is desaturated forcing to tap the groundwater from deeper aquifers of 100 m depths leading to deeper groundwater levels (>20 meter below ground level) at places and 4 hydrographs out of 10 are showing declining in water level trends in both seasons. Water table varies from 455-535 m a msl with groundwater flows towards central part of the basin. The transmissivity varies from 45-190 m²/day and specific yield from 0.35 to 1.3%. The recharge due to rainfall varies from 2 to 15% and from irrigation return flow from 8 to 17.4%. Overall the stage of groundwater development (GD) varies from 44% to 120% in the area with average of 79%. The average concentration of fluoride, nitrate and electrical conductivity is 1.7ppm, 66 ppm and 820 micro siemens/cm and 1.67 ppm, 68 ppm and 724 micro siemens/cm during pre and post-monsoon season respectively and 50 % of samples are unfit for human consumption and it is also observed that F concentration is high in structurally controlled areas during post-monsoon season and it reduces marginally along the pumping period. Out of 12 water stress periods (3 years), only 3 shown a positive balance in volumetric balance with 45m³/day/cell and in other it was -61 to -987 m³/day/cell.

For suggesting zone-wise sustainable groundwater management plan, potential surface runoff of 0.83 MCM is considered and suggested 38 site specific artificial recharge structures (ARS) in 13 mini-watersheds, cultivation of irrigated dry (ID) crops, adaptation of micro irrigation techniques along with provision for alternate source of drinking water. Desilting of existing tanks and participatory groundwater management, creating various awareness activities along with strict implementation of regulatory measures. The approach and the outcome of the study will go a long way for upscaling in similar hydrogeological environs of the country.

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Session Classification : Parallel

Track Classification : Topic 3.1 - Groundwater and water security in developing countries
Local meteoric water line of southwest Spain

Tuesday, 24 September 2019 16:00 (60)

The objective of this study is the analysis of stable isotopes (18O and 2H) of rainwater in southwest Spain to determine the local meteoric line and to investigate the origin of the vapor masses. A 5-L polyethylene bottle containing paraffin oil to impede evaporation was installed at two sampling stations: Plaza de España located in the city of Seville (Urban area) and Doñana National Park at the province of Huelva (Rural area). We evaluated 72 samples taken from 2014 to 2018. Isotopic samples were analyzed with a Laser spectroscopy system (Model L1102-i, PICARRO). Results show a representative Local Meteorological Water Line (LMWL) for southwest Spain and isotopic variations and their dependence on the origin of the vapor masses using satellite images of meteorological situations and local meteorological data. Furthermore, the importance of thermal influences and the existence of a continental effect will also be analyzed by comparing the isotopic signals of the two locations.

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Session Classification : Poster with refreshments
Track Classification : Topic 5 - Tools, methods and models to study groundwater
Residents living in karst area barely find clean water resources for their daily needs. Typical karst geological settings which consist of easily dissolved limestone cause groundwater to be accommodated in caves, underground rivers and random subsurface veins. Underground dam could be the best solution for groundwater assessment and management due to its complexity. Its construction captivates and gathers all the water from the various veins then stores it behind the intake wall. The southern part of Okinawa Island is a sea shore area where Ryukyu limestone spreads well. It has many livestock farms as well as numerous agricultural fields growing vegetables and sugarcanes. There was not enough surface water for agricultural and domestic use. To meet those demands, Komesu and Giza Subsurface Dams were established in 2005. The objectives of this study are to determine the environmental effects and the effect of those subsurface dams to the groundwater quality and quantity, using multiple stable isotope analysis (N, C and S isotopes/ CNS-IT). The result showed that Komesu and Giza Subsurface Dams were able to hold the groundwater at one area. Especially during the rainy season, the groundwater level could exceed Komesu’s intake wall (70m) and outflow the underground dam. Nitrate concentration in the groundwater was relatively high, nitrate as nitrogen concentrations were more than 10 mg/L (20 of 69 observation points). Nitrate and sulfate isotopes analysis presented the groundwater was contaminated by chemical fertilizer, with the value of deltas nitrogen-15 mostly around 6-14‰ and deltas sulfur-34 approximately -2 to 5‰. Indeed, the deltas nitrogen-15 versus the deltas sulfur-34 plot proved that autotrophic denitrification happened across the basin. Carbon isotopes traced the major source of the carbon came from terrigenous soil which were planted by C4 plants with value of deltas carbon-13 around -10 to -16‰. Meanwhile, Komesu Underground Dam had also proved that it could block the seawater intrusion. Total dissolved solid value at the outside of the dam was around 1200 and 400-600 inside the construction. The long term monitoring data would be presented before and after the underground dam construction.
Session Classification: Parallel

Track Classification: Topic 7 - Karst Hydrogeology
Nitrogen and phosphorus compounds in coastal multi-aquifer post glacial hydrogeological system: case study in Puck region (northern Poland)

Tuesday, 24 September 2019 16:00 (60)

We report preliminary results from geochemical characterization of a coastal multi-aquifer groundwater system, which has been carried out in the framework of the project "Modelling of the impact of the agricultural holdings and land-use structure on the quality of inland and coastal waters of the Baltic Sea set up on the example of the Municipality of Puck region – Integrated info-prediction Web Service WaterPUCK", funded by National Centre for Research and Development (NCBR), Poland, (BIOSTRATEG3/343927/3/NCBR/2017). One of its main aims is to quantify the presence of nutrients (nitrogen and phosphorus compounds) in groundwater and their potential impact on seawater quality in the Puck Bay, which is a part of the Baltic Sea adjacent to the Polish coast and separated from the open sea by the Hel Peninsula.

The investigation area is covered by young glacial sediments and consists of moraine uplands and deep cut ice marginal valleys. Groundwater occurs in form of small perched aquifers on top of glacial till, as well as two main Quarternary aquifers, which have their outcrops in the sea bottom of Puck Bay, within 1-5 km from the coast. The land is used mostly for agriculture and forestry.

Groundwater samples were taken from 85 sampling points, including dug wells (mostly in perched aquifers), drilled wells (mostly in the shallow Quarternary aquifer), springs and boreholes. There are clear differences in nitrate (NO3) concentration between the shallow dug wells (10 to 90 mg/L) and deeper drilled wells (generally below 2 mg/L). The concentrations of ammonium (NH4) are similar in both groups of wells, while the concentrations of phosphorus (PO4) are mostly between 0.1 and 10 mg/L, with the average value slightly higher in the shallow wells. In this work we will present a detailed analysis of spatial and time distribution of the concentrations of nutrients and major ions in the area and we will discuss the potential impact of groundwater on the seawater quality.

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Session Classification : Poster with refreshments

Track Classification : Topic 8 - Groundwater quality and pollution processes
In view of the increasing use of groundwater resources worldwide, there is a need to develop efficient methods to quantify the natural recharge rate and the time of migration of contaminants from the ground surface to the groundwater table. These two tasks are closely related, since they both require knowledge of water velocity in the vadose zone, which is generally variable in space and time. In order to achieve this goal, numerical models of unsaturated flow and transport are often used. Nevertheless, the widespread use of numerical modeling is still hampered by the limited availability of realistic data for specific scenarios, need for the user expertise, relatively long times of computation and possible convergence problems in transient flow simulations. For this reason, simplified approaches to quantify recharge and contaminant travel time remain a useful tool in hydrogeological practice. In this work we focus on the comparison of transient flow and transport simulations with the simplified methods for soils showing heterogeneous (layered) structure.

We performed numerical simulations of transient water flow and solute transport using the SWAP computer program for 10 layered soil profiles, composed of materials ranging from gravel to clay. In particular, sensitivity of the results to the thickness and position of weakly permeable soil layers was carried out. Daily weather data set from Gdańsk (northern Poland) was used as the boundary condition. Two types of cover were considered, bare soil and grass, simulated with dynamic growth model. The results obtained with unsteady flow and transport model were compared with simpler methods for travel time estimation, based on the assumptions of steady flow and purely advective transport. The simplified methods were in reasonably good agreement with the transient modeling approach for coarse textured soils, but tended to overestimate the travel time, if a layer of fine textured soil was present near the surface.

The work is partly funded by National Centre for Research and Development (NCBR), Poland, (BIOSTRATEG3/343927/3/NCBR/2017 "Modelling of the impact of the agricultural holdings and land-use structure on the quality of inland and coastal waters of the Baltic Sea set up on the example of the Municipality of Puck region – Integrated info-prediction Web Service WaterPUCK") and by National Science Centre (NCN), Poland (2015/17/B/ST10/03233 "Groundwater recharge on outwash plain").
STUDY OF THE RESPONSE OF VARIOUS HYDROLOGICAL SYSTEMS TO SEVERAL STORM EVENTS NEAR THE CITY OF MALAGA (SPAIN)

Tuesday, 24 September 2019 16:00 (60)

The Guadalhorce River flows in the South of the Iberian Peninsula and ends in the West of the city of Malaga (Spain). Its peak discharges take place usually after important, high intensity storm events (>50 mm/day), and it reaches flows up to 1,200 m³/s, which cause a relevant rise of the river stage.

Previous researches have verified that a relationship exists between the different hydrological systems taking place here: the Guadalhorce River, the subjacent aquifers, the wetlands and the Mediterranean Sea. To check this phenomenon in detail, a monitoring network composed by data loggers was installed. These devices record, hourly, river and wetlands stage, groundwater table in wells, as well as electrical conductivity and temperature of waters in wetlands and aquifers. Data loggers allowed to record the behavior of systems between 20/11/2016 and 15/12/2016, when several and intense storm events took place, some of them up to 79 mm/day.

Each one of these storms caused an important increase of Guadalhorce River stage (>1 m), in first place, because it is the hydrological system most sensitive to rainfall. Quaternary aquifer (unconfined) also responds after a few hours, but the behavior of the peaks is very similar to the one showed by the Guadalhorce River, excepting in some points, further from the coast line and the river, where levels remain higher after the storms. Pliocene aquifer (confined) groundwater table shows retarded response respecting Quaternary aquifer and Guadalhorce River. Wetlands’ stage has also a very fast rise due to direct precipitation, but a slight increasing slope is appreciable after this. In the last point, evaporation and groundwater output from wetlands are visible with noticeable decreases. In most of the points, noticeable diminutions of the electrical conductivity of waters are visible when these storms take place because of freshwater recharge. Finally, water temperature of all water bodies diminishes due to the contribution of recharge water, colder.

The monitoring of several hydrological systems using continuous recording devices have allowed to discern their response to rainfall, which takes place in different ways. Guadalhorce River is the first water body showing it, followed by the Quaternary aquifer, the wetlands and the Pliocene aquifer, respectively. This suppose a connection between systems where, at least in high water conditions, precipitations recharge all of them but there is also water flow from the Guadalhorce River towards the Quaternary aquifer and, finally, to the wetlands, with a slight buffer effect. Pliocene aquifer looks to function other way because of its confinement. Different magnitude in variation of groundwater table, electrical conductivity and temperature in the Quaternary aquifer proves variable hydraulic conductivities in this aquifer, which look to be higher in the zone closer to the north arm of the Guadalhorce River splitting.

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Session Classification: Poster with refreshments

Track Classification: Topic 6 - Groundwater, wetlands and natural heritage
What does it take to get recharge in a semi-arid climate?

Tuesday, 24 September 2019 12:00 (15)

Detailed monitoring of an exceptional rainfall event of 180mm in 36 hours over the 385 km² semi-arid Fowler’s Gap catchment of western New South Wales is analysed. Fifty-year average annual rainfall is 243mm. The event was captured on 20 tipping-bucket gauges, 2 creek level gauges, by a full climate station, water levels in 12 bores and a group of 6 thermal arrays buried in the creek. Rain in the first 24 hours was the 6th heaviest 24-hour total on a 50-year record of daily events. The final 24-hour event was the highest total on record.

Fowler’s Gap Creek rises on highly folded and faulted Precambrian rocks and passes through a small gap in a ridge of these rocks to spread out onto a plain of Mesozoic and Cenozoic sediments before collecting in the endorheic Lake Bancannia, approximately 45 km downstream from Fowler’s Gap. The groundwater and thermal monitoring were arranged to determine the fate of water spreading out onto the Cenozoic Plain.

The creek bed is comprised of loose coarse sand and the flood front took 11 hours to travel 16km downstream. The build up of water behind the front reached a depth of 1.75m within 15 minutes and approximately 4m depth at the height when the water spread to cover the flood plain.

Two bores installed in the creek were dry (13m and 6m depth to bedrock) prior to the storm event. There was no indication of any downward movement of water at either site until both became submerged by the flood and water entered directly via the well casings. Standing water remained in the creek channel for 24 days as measured by a bubbler gauge. The basal temperature sensor at 1m depth recorded water for 49 to 42 days at two thermal sensors.

With the exception of the direct recharge down the piezometer pipe, no borehole has shown any evidence of recharge in the subsequent 4 years of monitoring. Groundwater occurs at 70m depth in a confined aquifer and at approximately 20m, also in a confined aquifer. All downward drainage from this major event must have been absorbed by the sands beneath the creek bed without bringing these sands to saturation. The River Red Gums have accounted for all the increased unsaturated zone storage by evapotranspiration. This major event did not lead to any groundwater recharge of the main aquifers.

Detailed field monitoring must be taken into account during regional groundwater modelling when, for a lack of data, recharge is simply assumed to be a fraction of annual total rainfall. As shown by this field example, recharge may still be zero unless many similar events occur each year to wet the subsurface.

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Session Classification : Parallel

Track Classification : Topic 2 - Groundwater and climate change
An absolute upper limit to specific storage has been determined using theoretical analysis and field measurements: What are the implications for groundwater modelling?

Specific storage ($S_s$) is often considered to be of secondary significance to hydraulic conductivity when groundwater models are populated with parameter distributions. The fact that there are very few example data sets to derive values of specific storage from, has meant that orders of magnitude parameter ranges are typically applied. This perception is reinforced by the belief that semi-confined conditions widely occur where the value of storage is considered to vary between an unconfined value of approximately 0.1 to 0.25 and a truly confined value of less than $1.3 \times 10^{-5}$. The validity of the semi-confined concept in groundwater modelling is reviewed and a new technique to determine confined/unconfined status is described based on an examination of Fourier band-pass filtered (2 cpd) time-series data measured in observation piezometers at a smectite-clay dominated site. The 2 cpd signal for atmospheric pressure is in phase for unconfined aquifers and moves to be out of phase by 180° when the aquifer becomes confined. Based upon the correct assessment of confinement, the selection of an appropriate specific storage value becomes significant. Use of $S_s$ values higher than the physically possible value of $1.3 \times 10^{-5}$ in groundwater models for confined aquifers implies that a completely unrealistic quantum of water is released from the REV when, in fact, the water must be coming from leakage or from much further afield. The use of unrealistic values of $S_s$ can thus completely underestimate potential environmental impacts. The implications for modelling are therefore significant.

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Session Classification :  Parallel

Track Classification :  Topic 5 - Tools, methods and models to study groundwater
Karst environments are characterized by distinctive landforms and unique hydrologic behaviors. They are known as a major source of drinking water around the world but also as highly complex and vulnerable hydrosystems. Their complexity and heterogeneity is related to their formation and evolution which are controlled by a wide range of geological, hydrological, geochemical and biological processes.

Karst hydrosystems' hydrology is usually modelled by applying lumped modelling approaches or methods assuming saturated hydraulic conditions and the validity of Darcy’s law. These models are mostly efficient for rainfall-discharge modelling at springs, but they do not account for the natural processes such as the multiple flow regimes and their consequences on the whole process of karst genesis and functioning. Such consideration requires 1) a deeper understanding of dominant natural processes that govern the initiation and evolution of karst systems in the short and long terms and 2) a subsequent modeling step to translate these physical pictures into quantitative computer models.

A review of the main modelling methods applied in each specific research domain will be proposed, with a specific focus on integration of various modeling techniques and its consequence on the understanding of the whole process of karst genesis and functioning.

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Session Classification : Plenary
Track Classification : Topic 7 - Karst Hydrogeology
Hydrogeochemistry and Occurrences of uranium and radon in Groundwater of Wonju, Korea

Tuesday, 24 September 2019 16:00 (60)

Uranium and radon concentration was assessed in groundwater samples collected from 40 private and public wells covering three hydrogeological units which is Jurassic biotite granite (Jbgr), Pre-Cambrian biotite gneiss (PCbgn) and Limestone (Ls). Water samples have been collected from 31 wells in Jbgr, 7 wells in PCbgn and 2 wells in Ls. Major ion concentrations and physico-chemical parameters were also measured. These results have given the basis for an attempt to characterize the groundwaters of research area with respect to uranium and radon content. Concentrations values ranged from 0.06 to 50.50 μg/L for 238U and from 67 to 8,410 pCi/L for 222Rn. The statistical analysis for 238U and 222Rn showed a log-normal distribution with a mean of 5.57 μg/L and 2,357 pCi/L, and a median of 1.55 μg/L and 1,915 pCi/L, respectively. Uranium concentrations were almost lower than maximum contaminant level for drinking water in U.S EPA. Three of 40 groundwater samples had levels of uranium that exceeded the maximum contaminant level for drinking water. About 20 % of the samples in 222Rn concentrations exceeded 4,000 pCi/L of US EPA’s Alternative MCL (AMCL) and 8,100 pCi/L of Finland’s guideline level, respectively. A hydrogeological study revealed correlations between the concentration of radionuclides and the aquifer material’s characteristics. Higher uranium and radon concentrations in groundwater are related to the granitic rocks. The correlation analysis between uranium and radon and other variables only a weak relationship between uranium and pH value (correlation coefficient 0.37 in uranium and radon, respectively). None of major ion concentrations showed a significant statistical correlation with uranium and radon. Uranium and radon concentrations in the groundwater is relatively low compared with other countries having similar geological conditions possibly due to the inflow of shallow groundwater to the wells.

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Session Classification : Poster with refreshments
Track Classification : Topic 8 - Groundwater quality and pollution processes
Isotopic preliminary characterization of meteoric waters and groundwater from the carbonate karst aquifers of Sierras de Segura, Castril and Seca (SE of Spain)

Thursday, 26 September 2019 16:00 (60)

The carbonate massifs of Sierras de Segura, Castril and Seca (SE Spain) constitute strategic groundwater reservoirs in the headwaters of the Segura and Guadalquivir drainage basins, the most important rivers in South of Spain. This area, covers around 660 km2 of land surface, belongs to the Prebetic geologic domain in the Betic Cordillera, where limestones and dolostones rocks of Cretaceous age predominate. The karstification phenomena on surface are intense as can be noted from the density of karst landforms, such as dolines (> 3500), poljes and ponors (> 300). This study comprises a preliminary characterization of the recharge waters and groundwater draining by the main springs from the spatial-temporal distribution of their isotopic signature (δ18O and δ2H). Thus, several field surveys for rainwater and groundwater sample collection have been conducted during an 18 months-study period. The results show a mixed origin of the precipitation sources, from Atlantic Ocean and from Mediterranean Sea, which a variable contribution depending the amount of the precipitation and its seasonality. Preliminary calculations performed using isotopic meteoric data present higher isotopic altitudinal gradients in the eastern slopes than in the western ones, which are consistent with the general decreasing trend of rainfall amount towards the East. The analysis of the stable isotopes of karst groundwater results in an elevation range of recharge from 1650 to 1800 m a.s.l., largely agreeing with the average height of the karst outcrops in concordance with the locations of karstic springs.

Keywords: carbonate karst aquifers, karstification phenomena, stable isotopes, isotopic altitudinal gradients, recharge elevation, Southern Spain.

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Session Classification: Poster with refreshments

Track Classification: Topic 7 - Karst Hydrogeology
Isotope and geochemical tracers to quantify seasonal variations of the water balance components in a groundwater-dependent low altitude Mediterranean peat bog (Corsica Island, France)

Thursday, 26 September 2019 11:45 (15)

Wetlands are key environments in watersheds with several essential hydrological functions such as flood mitigation, support for low water flow or improvement of water quality. Some of them, in particular, the peat bogs, are also known for their carbon storage capacity. Nevertheless, peat bogs are poorly studied in the Mediterranean while in such context carbon storage capacity could be strongly threatened by their drying up due to global warming.

A hydrogeological study is currently conducted on one of the southernmost low altitude Mediterranean peat bog located in Moltifao, Corsica Island, France. The Moltifao peat bog (40,000 m² and from 240 to 270 masl) is connected to an alluvial aquifer and situated between the Ascu torrential River and surrounding granitic massifs which makes its major ecological specificity and its high international importance (RAMSAR). The objective of this study is to evaluate the potential of a combined isotope and geochemical approach to quantify seasonal variations of the water components that may condition water fluxes and carbon cycle processes in such a Mediterranean context.

To reach this objective, 5 quarterly field campaigns in contrasted hydrological conditions were carried out from May 2018 to June 2019 through a network of 26 sampling points. The investigations involved a hydrodynamic and multi-tracer approach, including stream flow and groundwater level monitoring, physico-chemical parameters, major ions, stable isotopes of the water molecule (18O, 2H) and tritium (3H). In addition, rainwater and stream water were collected monthly for the characterization of the local stable isotopes framework.

Groundwater level measurements showed the relative contribution of the alluvial aquifer, rainfall regime and direct surface runoff from the surrounding granites on the recharge of the Moltifao peat bog. Geochemical and isotope tracers also highlighted seasonal variations in the alluvial groundwater recharge from the granites and from the Ascu River. The Ascu River water is characterized by low electric-conductivity (EC) and neutral water type, whereas groundwater from the granites controls the mineralization with higher EC and a Na-SO₄ water type. Water from the alluvial aquifer shows an intermediate EC, a Ca-Na-Cl water type and a higher Si content. These strong variations in geochemical and isotope signatures allows quantifying the relative input from all water bodies involved in the peat bog recharge over the seasons.

From these first data, a water budget of such Mediterranean peat bog is proposed. This is an initial stage before a further study on carbon cycle processes from organic (DOC, TOC) and inorganic (DIC) carbon contents and associated isotopes (13C-DIC and 14C-DIC) intended to inform on the peat bog carbon storage capacity facing drying up related to seasonality and climate projections.

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Session Classification: Parallel

Track Classification: Topic 6 - Groundwater, wetlands and natural heritage
Characterization of preferential flow paths is important for assessing the delivery of treatment amendments to contaminated portions of an aquifer. Field investigation methods with high spatial resolution are required to capture the flow variability in unconsolidated or discretely fractured aquifers, and to identify the nature of flow pathways (i.e. fracture vs matrix flow) relative to the contaminant distribution. The active distributed temperature sensing (A-DTS) method, originally developed for fractured rock boreholes, was adapted for application in a poorly cemented sandstone aquifer contaminated with chlorinated solvents in southern France.

The composite fiber optic cable was attached to a PVC pipe and grouted in the borehole to avoid cross-connected flow and to recreate natural-gradient flow conditions in the aquifer representative of flow conditions over the past decades of plume transport at this aged contaminated site. The A-DTS tests consist of heating the cable for up to 24 hours with constant heat input and recording temperature along the cable continuously using a DTS unit. Active groundwater flow in preferential flow paths causes an enhancement of heat transfer from the cable creating a cooler thermal response than zones with lower or no flow. The geometry of the test was recreated in a numerical heat transport model and a relationship was developed between the thermal responses measured with the A-DTS, and the volume of water flowing through the preferential flow paths.

The results show variable flow rates along the borehole indicating the presence of preferential flow zones. A fluorescein tracer injection experiment followed by detailed core logging and sampling, with visual inspection of fluorescein tracer distributions under UV light to guide high frequency, depth-discrete rock core sampling, provided additional evidence for the presence and distribution of preferential flow paths, also indicating flow anisotropy and tracer transport retardation. The results from these two methods, combined with detailed profiles of contaminant concentration distribution from rock core and groundwater sampling, inform and optimize the design for in-situ remediation.

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**Session Classification :** Parallel
Track Classification: Topic 5 - Tools, methods and models to study groundwater
Groundwater resources in Chile: the required revision of conceptual models to cope with anthropogenic and climate pressure changes

Along the western edge of the Andes, from the semiarid and mediterranean areas of Central Chile to the hyperarid Atacama Desert to the North, climate changes together with a significant increase of water demand has led to strong pressures on the water resources. In Chile, since the late 1980s, the growth of exports (minerals, agricultural products) increased the water demand. As a consequence, severe withdrawals have been registered in surface-water (river, lake, dams) and alluvial aquifers. These hydrological reservoirs being highly sensitive to precipitation changes and water extractions, negative water balances are common along the northern half of Chile even if there are restrictions for new private water rights. This results in a decline of the water levels of rivers, dams or shallow alluvial aquifers sometimes submitted to severe depletion.

Today, water scarcity is impacting all aspects of the Chilean society (landscape, water supply, irrigation, industry, etc.) and water-resources issues become more and more a matter of concern. Surely, the general poorly knowledge of aquifers functioning (geometry, boundary conditions, recharge processes, water ages), leading to unsuitable local management plans to cope with actual water challenges.

Recent studies have highlighted that Chilean traditional approach of aquifer conceptual models need to be reviewed. An example, that supports the need to have conceptual models more in line with the complex hydrogeological reality of Chile, is the new insight about the role of Andean Piedmont and Western Front in recharge processes of the sedimentary basins aquifers. Reservoirs so far neglected by management plans (e.g. fractured medium, complex architecture aquifers) may provide different perspectives for the groundwater resource exploration in Chile.

Effort have to be done in academia, water authorities and whole society to provide trained professionals, rules and knowledge that will face properly and in time with water resources issues due to the increasing anthropogenic and climate changes.

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Session Classification : Poster with refreshments

Track Classification : Topic 2 - Groundwater and climate change
Why Managed Aquifer Recharge is a successful tool to Climate Change adverse effects adaptation? Examples and indicators

Monday, 23 September 2019 16:00 (60)

Managed Aquifer Recharge (MAR) has been considered for a long time as an important technology to combat the adverse effects of Climate Change (CC). This is not a gratuitous claim. In this article, the authors will support this statement on the basis of real sites, indicators and international cases. Examples from five continents together with figures and trends will demonstrate that MAR, in combination with other measures of Integrated Water Resources Management (IWRM) are able to conduct adaptation and even mitigation activities against climate change challenges.

The main effects of climate change are raising the average atmospheric temperature, decreasing average annual precipitation, causing extreme weather and inducing sea level rise. These result in a series of negative impacts reflected in an increase in certain parameters or events, such as evaporation, evapotranspiration, water demand, fire risk, floods, droughts and saltwater intrusion; and a decrease of others, such as in water resources availability, run-off, modified wetland areas and hydro electrical power production.

MAR is a flexible tool with a wide array of techniques that can address not only different objectives, but also a mix of goals. Examples taken from different MAR systems all around the world have been selected to show their effectiveness to mitigate the problems previously mentioned. Solutions include underground storage, temperature decrease, soil humidity increase, reclaimed water infiltration, punctual and directed infiltration, self-purification, off-river storage, wetland restoration and/or establishment, gravity flow water distribution, power saving, eventual recharge of extreme flows, multi-annual management and intrusion barrier wells, as most remarkable activities and effects.

As success must be measured, some indicators have been adopted or designed so as to calculate and quantify the actual influence of these solutions, their trends and even some benchmarking actions have been applied to compare the general evolution from different places. These have been expressed in the form of volumes, lengths, areas, percentages, grades, euros, CO2 emissions or years. Therefore, MAR demonstrably supports its usefulness in battling climate change impacts in a variety of environments and circumstances.

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Session Classification : Poster with refreshments

Track Classification : Topic 2 - Groundwater and climate change
Spanish Careos and Peruvian Amunas. Comparative analyses for pioneer managed aquifer recharge systems

Monday, 23 September 2019 16:00 (60)

The most ancient written references for MAR Recharge are the Careos, in the South of Spain, and the Peruvian Amunas. Both high mountain systems are complex and present extraordinary analogies and differences, despite being chronologically Pre-Columbian structures in the case of Amunas. From both there are written chronicles since the XII Century and both evolved in parallel, although disconnected, with amazing similarity.

After studying in detail 10 Careos and 6 Amunas from a construction techniques perspective, they have been decomposed in 24 different components. All these units have been compared, studying their analogies and differences according to the employed materials, hydraulic masonry, mortar types, carved stones, layout, profiles, relationships between the different elements, water origin and treatment and water recharge. Units’ pathology and recovery measures have also being studied by means of polygonal, linear or punctual structures.

Some common points are the low rainfall conditions, temporal water availability from snow smelt and runoff, induced recharge by means of infiltration fields, canals, ditches and simas, subsurface and deep groundwater transit and recovery from springs or irrigation ponds.

Some of the differences are based on the form of carving the stone and masonry, maximum flowrate capacity from 200 l/s to 800 l/s, distance between consecutive canals, time of transit (15 days to 7 months), recovery flow rate from 1 to 5 l/s (respectively for Amunas and Careos), etc.

In both MAR cases, ancient structures work as a hydrogeological and socio-cultural complex system, with values, norms and traditions scarcely evolved in 8 centuries. Water management is accompanied by land and crops management too, to the extent that both can be considered a cultural met in the distance or “cosmovision of water”, as there are certain evidence of synchrony in their temporary development.

Both systems fit the definition for Adaptive Complex System (Murray, 2010) as a articulated group of subsystems with self-similarity, complexity, and self-organization, rather than a Multi-Agent or system, defined as a composed system with multiple agent in permanent interaction (Wooldridge, 2002, for artificial intelligence).

Finally, the article recommends some improvement advices, based on their cross-comparison. It also studies the possibilities of replicability for other ridges of mountains in the world and suitability to face climate change adverse impacts.

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Session Classification : Poster with refreshments

Track Classification : Topic 3 - Groundwater sustainability and governance
Integrated water resources management advances in Ica aquifer, Peru. Improvement actions based on Managed Aquifer Recharge technique

Friday, 27 September 2019 10:10 (15)

Ica is located on the South Coast of Peru and counts on the most advanced agro-industrial development of the country. Agricultural production depends on groundwater availability, and since 2012 JUASVI and ANA have implemented more than 700 infiltration ponds for intermittent use. So, it has become one of the largest scale MAR systems in America, and it is providing lessons beyond those from pilot-size sites.

MAR is combined with different IWRM techniques, providing an example about MAR is a piece of a multi-component system, not able to solve water scarcity and drought situations by itself, but the technique becomes powerful when it is combined with additional water harvesting and management multipronged resources and mechanisms.

Water is taken from Ica River during the rainy season, stopped by specific constructions, retained in decantation ponds and later directed at infiltration ponds (pozas) interspersed along the aquifer.

Some specific lines of action to improve the system already applied are:

- Structures to retain water from Ica River minimizing the volume finishing in the Ocean
- Over-floods management with a certain predictive component
- Aquifer knowledge and its behavior improvements, so as to set new infiltration ponds in the most suitable sites
- Creation of an integrated and interconnected water management system
- Monitoring network in real time
- Clogging fight and high efficiency maintenance operations
- Search for alternative sources of water such as WWTP, transfersences, irrigation return, etc.
- Coordination and communication improvement

Some alternative lines of action are based on the use of gravity dikes, underground dykes, river basin’s slopes treatment and SUDS.

It is also worth to mention the support of local authorities and difficulties to reach agreements between the different agents within the basin (from the mountain to the sea) which have different interests leading to eventual water conflicts. Apart from the technical and social barriers, the total dependence of rainfall is forcing to seek new sources of water and alternative mechanisms, from WWTP to SUDS implementation.

MAR is in the Peruvians idiosyncrasy (Incans recharged intentionally from at least the XII Century), so, by means of single surveys, it is possible to find out new susceptible areas to build new “pozas”. In seven years of operation it is worth to mention that clogging damage is not remarkable yet, infiltration rates have barely changed and cleaning and maintenance activity is inviting to new owners to provisionally loan their terrains for new infiltration ponds.
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Session Classification : Parallel

Track Classification : Topic 9 - Groundwater and socio-economic development in Latin-America
Groundwater Recharge Based on Semi-loose Coupling Model: A Case Study in Su-mi-huai Area, Beijing

Tuesday, 24 September 2019 16:00 (60)

In order to quantitatively analyze the variation of rainfall infiltration recharge resources obtained by groundwater under the condition of changing underlying surface and the relationship between surface water and groundwater conversion in mountainous-plain areas, the long time series SWAT runoff model and the groundwater recharge from mountainous area to plain area in Su-mi-huai area of Beijing were selected as transfer variables to replace rainfall infiltration recharge and lateral recharge in the piedmont region in MODFLOW model, respectively. The simi-loose coupling SWAT-MODFLOW was established. Through verification, we found that the coupling model can accurately depict the change of groundwater level in this area, and the method of transferring rainfall infiltration recharge to MODFLOW model can reflect the recharge ability of groundwater in SWAT model. The rainfall infiltration recharge calculated by the coupling model is $1.31 \times 10^8$ m$^3$/a, which is $0.54 \times 10^8$ m$^3$/a less than that calculated by traditional rainfall infiltration coefficient method. It reflects that when the underlying surface conditions change and the thickness of vadose zone increases, the rainfall recharge of underground aquifer decreases.

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Session Classification : Poster with refreshments
Track Classification : Topic 5 - Tools, methods and models to study groundwater
Improvement and Application of SWAT Model in Southwest Karst Region—a case study in Lijiang River Basin

Thursday, 26 September 2019 16:00 (60)

In the karst peak forest area of southwest China, it is difficult to quantitatively characterize the process of groundwater recharge by traditional hydrogeological methods due to the spatial heterogeneity caused by strong carbonate karst development and the influence of surface karst zone on rainfall infiltration. Based on the open-source SWAT model and by improving the soil water and groundwater modules, the process of soil water entering groundwater through rapid flow by wide fossils and slow flow via small fossils was characterized in this study. A distributed hydrological model suitable for karst area was built, which was calibrated and validated using the case in Lijiang River Basin in Guilin City of Guangxi Province. The results showed that compared with the original model, the distributed model has a better efficiency on simulation of regulation and storage function of surface karst zone and dry season simulation in each hydrological station. The Nash coefficient of Chaotian station is increased from 0.78 to 0.92, and the determination coefficient is increased from 0.85 to 0.92, which is obviously higher than that without improvement. The improved model can be applied to the simulation of water cycle in karst basin with uneven distribution of clastic rocks and carbonate rocks, which provides a good technical support for the rational exploitation of groundwater in the study area.

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Session Classification : Poster with refreshments
Track Classification : Topic 7 - Karst Hydrogeology
Realization and Application of solute transport coupling model in discrete conduit-continuum systems

Thursday, 26 September 2019 16:00 (60)

Numerical simulation of solute transport is one of the most important techniques for studying groundwater pollution prevention and control. The strong heterogeneity of Karst aquifer medium causes great difficulties for simulating groundwater solute transport. Based on groundwater flow model of MODFLOW-CFP, we establish a solute transport model for coupled discrete conduit-continuum systems. In order to overcome the excess and numerical dispersion produced by finite-difference and finite element methods, upstream weighting method and Crank-Nicholson scheme are combined to solve the one-dimensional groundwater solute transport equation which is suitable for conduit flow. The accuracy of the solution is proved by the fitting of analytical solution and the conservation principle of the solute mass. Solute transport in continuum system is solved by MT3DMS code. Comparing with MODFLOW-CFP, solute exchange in pipe nodes between pipe system and continuum system is critical, that can use FORTRAN to implement it. The model was then employed in simulate solute transport in Xianghualing, Hunan Province, the results showed that the established coupling model is valuable and conduits have strong influence on the concentration field.

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Session Classification : Poster with refreshments
Track Classification : Topic 7 - Karst Hydrogeology
The piezometric tidal signal, a new tool for studying the properties of even the shallowest aquifers

Ocean tides induce a tidal signal in coastal aquifers. The same applies to the Earth’s solid tides, which induce a piezometric tidal signal far inside continents. This signal has been observed and studied for several decades in oil reservoirs, some mines and some confined aquifers. Since the influence of the Moon and the Sun is everywhere, it can be assumed that the piezometric tidal signal is universal and we have tested this hypothesis by studying piezometric records on unconfined, shallow aquifers. Our observations confirm the existence of a piezometric tide in all aquifers, including the shallowest.

The signal amplitude is small (2 to 10mm). Oscillations can thus go unnoticed or be masked by other phenomena (barometric variations, rain, pump start-ups, etc.). To study the piezometric tide, rigorous signal processing is therefore required (barometric compensation, high-pass and low-pass filters).

Harmonic analysis of the signal highlights the main components of the Earth tides, where solar and lunar semi-diurnal components (M2 and S2) predominate.

The piezometric tidal signal reflects the aquifer’s response to a well-known periodic disturbance (the Earth tide). This makes it all the more interesting: it serves as a universal instrument for studying the properties of shallow aquifers (the most widely used by humankind).

To test this instrument, we have multiplied high-precision piezometric records in 50 wells in 6 countries across Europe and Africa. This paper sets out the first lessons learned from these measurements:

- The piezometric tide has a specific signature for each aquifer (and it is identical within very large portions of each aquifer);
- The signal is not just a simple sinusoid (which can be defined by its amplitude and phase); its complexity reflects that of gravimetric forcing, as well as the structure of the aquifer;
- The amplitude of the signal is related to the storage (S) of the aquifer; piezometric tides could thus be extremely useful for determining S;
- The phase shift of the signal (relative to the Earth tides phase) is not constant; it varies during the lunar month and differs from one aquifer to another;
- The shape of the signal is much more complex than that of the Earth tide; it sometimes includes multiple peaks and hysteresis effects, which in all likelihood reflect the complex structure of the aquifers themselves.

In conclusion, the piezometric tidal signal constitutes a new instrument for investigating the properties of aquifers. This method is particularly useful for studying aquifers where conducting very long-term pump tests is unfeasible, and aquifers where only one observation well is available.

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Session Classification : Parallel
Track Classification: Topic 5 - Tools, methods and models to study groundwater
Vulnerability assessment of seawater intrusion potential using GALDIT index model—Case of Cox’s Bazar aquifer, Bangladesh

The Cox’s Bazar region at the south-eastern coast of Bangladesh has gradually been changed from a rural settlement into a densely populated urban area, caused by the rapid growth of tourism. Nearly 2 million visitors visit every year due to its unbroken 120 km long sandy beach in the dry period of the year. Especially the largely increased fresh water demand of the touristic destinations, mainly covered by pumping of groundwater, is threatening the groundwater resources and its sustainability in the coastal aquifers. Additionally, water resources in this area are exploited without any metering and regulations. Hence, overexploitation and seawater intrusion has been identified as major risks counting on the groundwater resource of Cox’s Bazar. However, the available information of hydrogeology and awareness of seawater intrusion vulnerability of this economically important aquifer is almost missing. In this context, to assess the vulnerability of seawater intrusion of the Cox’s Bazar coastal aquifer, a qualitative approach of GALDIT assigned first time to this alluvial coastal aquifer. GALDIT is GIS-based approach that considers hydrogeological parameters to assess the aquifer vulnerability. Six parameters that are mostly controlled the seawater intrusion, have been used in this approach, i.e., (i) ground water occurrence, (ii) aquifer hydraulic conductivity, (iii) depth to groundwater level above the sea, (iv) distance from the shore, (v) impact of existing seawater intrusion and, (vi) aquifer’s thickness. Several maps are developed based on these six important parameters and finally overlapped them for final vulnerability map of Cox’s Bazar coastal area. The results of the vulnerability index modelling depict that the area close to the Bay of Bengal and Bakkhali river is more vulnerable to seawater intrusion than the south-eastern part of the study area. The results of this research also revealed that 9% and 78% of shallow wells are highly and moderately vulnerable to seawater intrusion, respectively, and 13% are potentially at low risk under the present condition. At the same time, considering sea level rise of 0.5 m would result in a substantial increase of the highly and moderately vulnerable areas in this coastal aquifer. In this case, 22% of the shallow wells (<50 m) are highly susceptible to seawater encroachment upon sea level rise. The consistency of the hydrochemical data with the vulnerability zoning map also indicates that for a sound and sustainable development of the Cox’s Bazar region, GALDIT index model can be an essential tool for the decision makers to determine the zones potentially vulnerable to seawater intrusion and to manage the available coastal groundwater resources.
Session Classification: Poster with refreshments

Track Classification: Topic 1 - Groundwater assessment and management
Assessment of groundwater resources in Beijing based on numerical simulation technology

Monday, 23 September 2019 16:00 (60)

Groundwater numerical modeling is the essential technique of groundwater movement research and groundwater resource assessments. By modeling the groundwater movement of Beijing, By the first joint modeling of Beijing groundwater in mountain and plain areas in this paper, the hierarchical evaluation of groundwater resources has been realized, and the impact of groundwater level variation on urban buildings is analyzed that based on the water distribution plan of the South-to-North water diversion project. These achievements can be used to optimize the water distribution plan and provide data support for reasonable conservation of groundwater.

Firstly, the Beijing hydro-geologic condition is generalized, the aquifer of the study area is divided vertically into five layers. The groundwater model is built by GMS and the study area is divided into 190 rows, 190 columns, 1 km * 1 km regular grids. Secondly, by using the monitoring data from 2013 to 2015, the model is identified and validated, the five aquifers are equilibrium analyzed, the groundwater recharge and excretion are calculated, the Beijing groundwater resources are evaluated that the recharge resources are $27.97 \times 10^8 m^3/a$, the exploitable resources are $24.8108 m^3/a$.

In the end, by predicting, in 2025 the phreatic water level would not exceed the limited water level for groundwater recoverable that the restrictions are the floors of underground engineering and landfill, therefore, it would not harm the urban architecture and environment when the South-to-North water diversion project lasts ten years.

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**Session Classification**: Poster with refreshments

**Track Classification**: Topic 1 - Groundwater assessment and management
Soil thickness approaching to adapt the COP method for groundwater vulnerability mapping to humid tropical karst

In geosciences, the direct application of methodologies developed in temperate climates do not always apply to tropical environments. One example is the application of the COP methodology created to assess the intrinsic vulnerability to contamination of carbonate aquifers when applied directly in a tropical country, such as Brazil. This methodology considers to estimate the vulnerability the properties related to the C=Concentration flow, O=Overlaying layers and P=Precipitation. In the parameter O, where the layers of soil and rock of vadose zone are used to measure the protection given to the aquifer, there is a significant difference between European karst and Brazilian tropical humid karst. Among main differences, we can mention thickness, texture and soil mineralogy. Whereas in European karst the soil thickness rarely exceeds 1,0 m, with predominantly clay minerals 2:1 and clayey silt texture, in tropical Brazilian humid karst soil layers are frequently thicker than 1,0 m with predominantly 1:1 clay minerals and strongly homogeneously textured clay. To evaluate these differences, simulations were performed for a study area located approximately 50 km from the city of Belo Horizonte (southeast region of Brazil) where the soil thickness of original methodology (Os subfactor) was multiple by 10X, 20X, 30X and 40X. In this way, other factors that could influence the protection of the aquifer were eliminated. With this, the same parameters for calculations in original methodology (varying only thickness) were considered. The purpose of these simulations was to demonstrate the influence of large soil thicknesses found in Brazilian tropical humid karst in comparison to the soil thickness found in European karst. The results showed considerable differences from the original methodology. The area is characterized predominantly by soils of the class Oxisol and clayey alteration material that directly cover the Proterozoic limestones of the Bambuí Group, belonging to the Sete Lagoas Formation. Stratigraphically, over the limestones are the metapelites of the Serra de Santa Helena Formation and Tertiary and Quaternary sediments. The simulations for the original methodology showed that the protection given by the soil layer will always be high due to a clayey texture characteristic (>30% of clay) and thickness greater than 1,0 m, as shown in the calculation of the subfactor Os. In fact, accounting for different soil thicknesses as a factor of modification from the original methodology, the results showed that there is a gradation of the high protection class for the moderate protection class. These simulations showed the need for modification of the original methodology for application in tropical environments. The direct application of the original methodology to tropical areas can lead to errors of protection class, which directly impacts the vulnerability assessment of an aquifer.

Keywords: vulnerability, simulation, vadose zone, soil thickness, protection.

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Session Classification: Poster with refreshments

Track Classification: Topic 7 - Karst Hydrogeology
The occurrence of antibiotics in groundwater, whether from human or veterinary use, is widely documented. Nevertheless, there are still few studies that address the hydrogeological and chemical factors governing their migration in aquifers, a paramount aspect to control groundwater quality. A detailed study in the Baix Fluvià alluvial aquifer (NE Catalonia) has provided remarkable insights about antibiotic distribution, potential sources of contamination and migration processes within the aquifer [1], as well as through the unsaturated zone. From its results, several observations related to water resources management arise: 1) the representativeness of the sampling wells within a complex flow-field of many simultaneously pumping wells, 2) the sorption and degradation of antibiotics and the effect on their transport, considering the multifaceted aspects of their geochemical behavior, 3) the extremely variable antibiotic load in manure, and 4) the patchy distribution of crops where manure is applied (cereals, forage) and those that not (orchards).

In addition, antibiotic infiltration was monitored in several experimental plots where fertilization was conducted using distinct slurry fractions from swine farms [2]. The antibiotic content in the soil at different depths, until 120 cm, was analyzed showing a high retention in the upper soil layer. Found antibiotic in soil water was also compared to the original antibiotic content of the slurry fraction used for amendment. While transport numerical models approximately reproduce the antibiotic profile in upper soil zone, they fail to simulate a credible pollutant mass balance. These discrepancies point out grave difficulties on selecting adequate sorption and degradation factors from existing references.

Both field studies bring out interesting observations about the fate and monitoring of antibiotics in groundwater. In this sense, inconsistent monitoring of antibiotic polluted groundwater at the aquifer scale will provide erroneous information, which will hardly support adequate management decisions. Moreover, despite soil data indicate that most antibiotics should be retained in the upper soil layers, they are paradoxically present within the aquifer affecting the quality of its resources. The outcome of this study points out the presently existing gaps and challenges on delineating prevention strategies for these pollutants of emerging concern and on the way that groundwater antibiotic data must be handled to efficiently support management actions. [Funded by project PACE-IMPACT, CGL2017-87216-C4-4-R].

Track Classification: Topic 8 - Groundwater quality and pollution processes
Pharmaceutical compounds occur in groundwater because of organic fertilization or the impact of human sources. Their fate in the subsurface is governed by hydrogeological and geochemical processes, which depend on the aquifer nature and the compound behavior along the flow path. Natural springs stand as locations where flow paths outcrop and, consequently, they bring information about the transport of these emerging contaminants, according to the nearby land use. Natural springs are therefore surrogate sampling points that characterize the pollution levels that will otherwise reach the water table and the whole groundwater system. Previous works indicated that nitrate, a side consequence of organic fertilization, had a distinct occurrence than the groundwater major geochemical components in natural springs [1]. A seasonal survey of pharmaceutical compounds at the same locations was conducted to compare their behavior related to the other hydrochemical components and obtain some knowledge of their fate in the uppermost parts of a hydrogeological system.

Eleven natural springs, which represent four distinct hydrogeological settings, were sampled in three distinct campaigns. Spring water was collected and analyzed for hydrochemical, isotopic, and pharmaceutical compound concentrations. Antibiotic gene resistance was also considered as a response of the groundwater microbiome to potential antibiotics and a way to measure their persistence effects on groundwater quality.

All sampled natural springs presented agricultural influence as pointed out by nitrate concentrations usually larger than 100 mg/L. Identified pharmaceuticals were tetracycline, doxycycline, clortetracycline, oxytetracycline, clindamycin, sulfamethoxazole and sulfamethazine, while other analyzed pharmaceuticals (up to 25) remained non-detected. Seasonal sampling pointed out a large variability of occurrences and concentrations. This variability is thus interpreted based on the local hydrogeological dynamic and sets some clues about their fate towards deeper zones of the aquifer system. Moreover, these results indicate the uncertainties to forecast emerging contaminant input concentrations derived from diffuse sources to streams, through natural spring discharge, and finally to groundwater. [Funded by project PACE-IMPACT, CGL2017-87216-C4-4-R and the grant H2020-MSCA-IF project RESOURCE (ID: 750104)].


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**Session Classification :** Poster with refreshments

**Track Classification :** Topic 8 - Groundwater quality and pollution processes
Estimating future stream connectivity using a water balance approach based on climate projections until 2100

Tuesday, 24 September 2019 11:30 (15)

Stream connectivity due to flow intermittency will be modified from its current pattern due to climate change. Restoring connectivity is then a matter of stream water availability within the basin, and it includes natural as well as man-induced factors. Among these pressures, the effects of global warming on the water budget are key to forecast the future behavior of each basin. Since stream flow is related to the hydrological balance, the response of river catchments to future climatic conditions can be implemented based on hydrological data.

Hydrological as well as ecological concern is interested on how climate change will affect stream connectivity and on the identification of the most sensitive basins, so feasible adaptation plans related to connectivity management can be implemented. This study takes considers stream connectivity in the Segre and Cinca catchments, located in the Pyrenees watersheds of the Ebro River basin (NE Spain), by coupling climate change scenarios and hydrological estimations.

From a methodological perspective, a water balance is estimated based on present data (1990-2017) to estimate the water budgeted components. Actual evapotranspiration is computed considering the basin land use distribution. A similar approach uses climate forecasts (Global Climate Model ECHAM5 (1961-2010); A1B) for this area in a 20-year periods until 2100. Climatic data result in an increase of temperature of 3.5°C in the Pyrenees and 3.1°C in the lower part of the central Ebro basin for 2100. Rainfall reduction is expected to be of 13.6 and 12.8%, respectively, for 2100. These projections are used to estimate the available water resources for the new hydrological conditions.

In this sense, available resources will vary from a 39% of the precipitation as in the period 1990-2017 to 32% in 2100 in the Pyrenees, and from 16% to 8% in the low lands. This will modify the mean value of the stream discharge in each sub-basin. Expected stream flow reduction will then have an effect on the aquatic states that determine the ecological status [1]. However, since flow duration curves can be described by a log-normal distribution, future curves can be plotted using expected mean discharge and its standard deviation. As a result, low flow aquatic states, namely hyporheic and arheic, will increase their number of days; meanwhile the state associated to high flows, named hyperheic, will also slightly increase. In summary, this new conditions will also affect the stream-aquifer interaction and the relevance of groundwater flow as a paramount factor to overcome potential impacts [Funded by project Odysseus - BiodivERsA3 2015-2016 Call - PCIN-2016-168].

Track Classification: Topic 2 - Groundwater and climate change
Overview of the hydrogeological investigations of recently discovered world class deposits in Serbia

Monday, 23 September 2019 16:00 (60)

Europe industry has growing concerns on availability of the raw materials. To address this challenge, the European Commission has created a list of critical raw materials for the EU, launched EIT Raw Materials initiative, and continuously support research projects (like INTRAW, UNEXMIN etc.) with the aim of reducing the dependency and meeting growing demands. In the last 15 years Serbia is experiencing new burst in geological exploration of mineral deposits. Currently 167 exploration licenses are active, covering approximately 6000 km2 or close to 7% of the territory. The most significant results of these efforts are discoveries of “Jadar” Li-B and “Čukaru Peki” Cu-Au world class deposits. It is estimated that from “Jadarite” mineral deposit 10% of worlds demand for lithium can be met. Among extensive geological exploration works, significant efforts were made on hydrogeological characterization of the ore body and surrounding rocks. Presented methodology of the hydrogeological explorations included application of water inflated packer systems for in-situ determination of hydraulic properties of deep hydrogeological units, installation of monitoring wells, pumping wells and aquifer testing, installation of deep (up to 2000 m) fully grouted multilevel vibrating-wire piezometers, deep groundwater sampling and levels monitoring. Based on collected data conceptualization of hydrogeological system was performed, which was followed with development of numerical groundwater flow models. Exploration works which are subject of this paper are related to prefeasibility and feasibility stage of the projects development and were conducted with the aim to estimate dewatering requirements, support mine and tailings design and assess the possible impacts on water resources and the environment. Specific challenges, which were identified during the project development, are related to frequent changes in mine infrastructure plans and interaction and continuous update between different project teams and elements. Since projects for opening of the new mines are long lasting and very complex, hydrogeology is present throughout the life of the project in different scales, starting from wider deposit area characterization to resolving site specific engineering issues. Experience from Serbia, along with the need for application of the industry best practice, emphasize the importance of improving the position of hydrogeology in local legislation and permitting procedures, in order to ensure proper groundwater resources characterization and protection.

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Session Classification : Poster with refreshments

Track Classification : Topic 1 - Groundwater assessment and management
NUMERICAL MODELING AS A TOOL FOR THE GROUNDWATER MANAGEMENT

In large Brazilian urban centers, where there is a complexity of land-use planning, water supply becomes worrying due to factors such as population concentration, increased demand, diversity in the types of uses, unrestrained tubular well drilling, climatic changes, besides water contamination. These factors, associated to the greater accessibility to well drilling technologies and inadequate groundwater management, hydrogeological studies was encouraged in certain regions that present high demands and evidence of an intense drawdown, such as in the Baquirivu-Guaçu River Basin - Guaruilhos (Sedimentary Aquifer System), Bauru (Guarani Aquifer System), São José do Rio Preto (Bauru Aquifer System), São José dos Campos-Caçapava-Jacareí (Taubaté Aquifer System), all in the Sao Paulo State. These areas are extremely dependent of groundwater, justifying the high number of existing wells. However, it was observed that about 70% of the registered wells do not have a concession, which could upset the adequate management of water resources. In this context of importance, and with the purpose of avoiding water collapses, the use of groundwater numerical modeling was highlighted as an important aid in the management of water resources, as it allows the understanding by the dynamics of complex hydrogeology systems, simulating future exploitation scenarios, and thereby enable important planning decisions to be made based on a well-defined technique. From the results of the numerical model, well based on a conceptual model, it was possible to identify critical or potentially critical areas, which may require drilling restriction and indicate other areas more suitable for drilling new wells; or allow drilling in the critical area as long as the grant of the new well is conditional on monitoring and detailed studies. This requirement causes more data to be collected by improving the numerical modeling and knowledge of the aquifer, in addition to avoiding possible inadequate exploitation. The management decisions aim to minimize the cost of extraction and increase the benefits of groundwater, and these decisions may be related to the definition of pumping regime and well flow; the most appropriate location for the drilling of new wells; of incentive programs for use or restriction; of programs of benefits or financial compensation, control of land use, among others.

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Session Classification : Poster with refreshments

Track Classification : Topic 1 - Groundwater assessment and management
Educational dissemination of geoscientific knowledge for geoconservation of the Brazilian groundwater: the Guarani Aquifer System case

Monday, 23 September 2019 16:00 (60)

Considered the fourth largest freshwater reservoir in the world, the Guarani Aquifer System (GAS) extends for about 1.2 million km² in South America. Its area of occurrence has a greater volume and extension in Brazil, but comprises also territories of Paraguay, Uruguay and Argentina. The GAS waters are contained in sandstone rocks formed in the Mesozoic Era, when much of the supercontinent Gondwana harbored a vast desert environment. During that period, the landscape was mostly sediments, accumulated in large sandy dune fields. In the transition from Upper Jurassic to Lower Cretaceous, a gigantic volcanic activity covered the dunes, originating thick lava flows that solidified on the desert sands and gave rise to the Serra Geral Formation. This unit constitutes, in most of its area of occurrence, a protection cover for the GAS waters. The waters are widely used in Brazil, both for agricultural production and for public supply. It is known that currently more than 1,500 Brazilian municipalities can supply themselves with the GAS waters, and may be compromised by industrial activities, agricultural activities, urban use, land subdivision, and land occupation without previous studies. Thus, studies that promote public policies aimed at its preservation are extremely important. The research is based on the concerns and goals of the Geo-School project – which proposes that any educator of the XXI century has the responsibility to raise awareness for the next generation, aiming to solve environmental problems accumulated over the years. The project seeks to reflect on new modes of production which do not imply the exhaustion of natural resources. The objective of this study is to identify ways to develop strategies towards disseminating geoscientific knowledge and to support the geoconservation of groundwater, promoting a continuous recognition and acknowledgement of the areas of occurrence of GAS. These strategies should enable people to understand the environmental aspects inherent to the local reality of the places where they live. By highlighting the importance of the geological heritage and the imperative need to preserve groundwater, the authors hope to contribute to the formation of a more conscious society and individuals more critical and sensitive to environmental issues. The diffusion actions of Geosciences involve initiatives of formal and non-formal education. The result is the elaboration of a geology-based website that will support the training of teachers and contribute to deepening conceptual actions. As long as new forms of dissemination are identified, such as social networks – with online pages and videos – the authors will expand their use as tools for the dissemination of geological and environmental contents.
Use of hydrogeological and hydraulic modelling for well and wellfield productivity forecast: case study of Jelgava Town, Latvia

Jelgava is 4th largest town in central Latvia with 60 thousand inhabitants. Centralised water supply of the town completely depends on groundwater. There is one main wellfield Tetele with 12 wells installed in the confined aquifer. Aquifer consists of upper Devonian sandstone with siltstone and clay interlayers lying at the depth of 156-260 meters from Earth’s surface. The well discharge varies between 1300-2100 m3/day, and the total planned discharge of the wellfield is 17.4 thousand m3/day. Static water level in the wells is 3-4 m above Earth’s surface (9.6 m amsl), and the drawdown in the wells is 11-23 meters. Daily 10 wells are in operation and two are kept as a reserve. Some decrease of well discharge had been observed therefore assessment of current well discharge and well loses as well as wellfield discharge and forecast of discharge decrease in time was needed.

Finite element transient 2D hydrogeological model was used to calculate water level changes in the wellfield area due to well discharge, well loss and well interference. Hydraulic model was used to calculate pressure loss in the water pipelines and their impact on well discharge decrease depending on piezometric level.

The hydrogeological model was calibrated on water level fluctuations in wells depending on well discharge regime using long-term SCADA data of the wellfield. The hydrogeological modelling yielded high accuracy results providing data on aquifer transmissivity and leakance, storage of sandstones and well loses and their changes in years 2014-2016.

Fluctuations of piezometric level in the aquifer and wells as well as wellfield discharge were simulated taking into account changes in well loses, well interference, technical parameters of submersible pumps and pressure loses in the water pipelines. Constant increase of well loss in two wells was found resulting in continuous decrease of well discharge. On the other hand, well loss in those wells correlated with the amount of water abstracted. Changes of well loses and related decrease of wellfield discharge in time were quantified.

It was concluded that wellfield discharge will decrease from 17 thousand m3/day today to 14.4 thousand m3/day in 10 years in the worst scenario. Some measures to postpone this some mitigation measures like similar discharge of all wells and other were recommended.

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Session Classification: Parallel

Track Classification: Topic 5 - Tools, methods and models to study groundwater
Infiltration and groundwater recharge dynamics in unsaturated fractured rocks: from pore-scale (multi-scale) smoothed particle hydrodynamics modeling to catchment response simulations

Recharge assessment in fractured (karst) aquifers is an essential component in groundwater management and in vulnerability estimation, concerning both, the quantification of the delay of the arrival of the recharge pulse at the groundwater table and of the storage volume of the vadose zone. In contrast to diffuse infiltration, frequently encountered in consolidated and unconsolidated porous media, the infiltration dynamics in the unsaturated zone of fractured-porous rocks and karst aquifers exhibits a rapid, gravity-driven flow component along preferential flow paths such as fractures, fracture networks, faults and fault zones. The partitioning into two hydraulically contrasting domains commonly leads to a breakdown of classical volume-effective flow equations employed in many FD or FEM modeling approaches which only consider the capillarity of the porous medium. Even in the presence of a porous matrix, preferential pathways along fractures have been shown to sustain flow percolation for equilibrium and non-equilibrium conditions. In order to properly capture the gravity driven film flow or drop flow physics along preferential vertical flow paths, various factors have to be considered such as static and dynamic contact angles, surface tension, free-surface (multi-phase) interface dynamics, dynamic switching of flow modes (between droplets, rivulets, films) and associated formation of singularities in the case of merging or snapping flow. Specifically, this presentation addresses (1) limitations of unsaturated multi-continuum catchment-scale simulations, (2) process-oriented infiltration dynamics along preferential flow paths with a parallelized 2D/3D smoothed particle hydrodynamics approach (SPH), and (3) pore-scale multiscale SPH modeling approaches to handle fracture-matrix interactions and transport phenomena in the small-scale limit when the advection-diffusion equation breaks down. Laboratory experiments were carried out to study some of the phenomena encountered, validate our code and obtain analytical transfer functions to study the given system in the large-scale limit.

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Session Classification: Parallel

Track Classification: Topic 5 - Tools, methods and models to study groundwater
Experimental study of solute transport in looping dual-conduit systems

Thursday, 26 September 2019 11:30 (15)

Solute transport in karst aquifers is primarily constrained to solutional conduits. An important phenomenon often encountered when interpreting tracer tests in karst aquifers is the occurrence of double-peaked breakthrough curves (BTCs). The double-peaked BTCs are usually attributed to tracer transport through a conduit system consisting of a dual-conduit structure: an auxiliary conduit that deviates from the main conduit at the upstream and converges back at the downstream.

In order to understand how the geometric configuration of the dual-conduit structure influences the BTCs, laboratory experiments utilizing plastic tubes were conducted. The looping structures were constructed by varying: 1) the total length of the conduits, while fixing the length ratio; 2) length ratio between the two conduits, while fixing the length of the main conduit; and 3) inlet flow rate.

Results show that the dual-conduit structure causes the double-peaks of BTCs. Keeping the length ratio of the two conduits and increasing their total length leads to a larger separation of the two peaks of the BTCs. Keeping the length of the main conduit while increasing the length of the secondary conduit causes similar effects. Increasing the inlet flow rate reduces the distance between the two peaks and the difference between the two peak values.

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Session Classification: Parallel

Track Classification: Topic 7 - Karst Hydrogeology
Geochemical and hydrochemical approach to a group of karstic aquifers in the South of Spain: Sierra de las Nieves y Sierra Gorda

The study of trace elements (TEs) is important in order to improve the knowledge for different po poises such biogeochemical cycles or anthropogenic release because may have harm for human and environment. Some of those trace elements are implicated in human health and disease even with rather lower concentrations.

This study is focused in some TEs of a group of carbonatic aquifer (limestones of Jurassic and dolostones and dolomitic marbles of Triassic) located in the south of Spain (Al, As, Cr, Fe, Sb and Zn) and TOC. This work has been carry out with data from the Geochemical Atlas of Spain. Ground-water quality data were provided by the Spanish Ministry of the Environment, although not all elements are sampled in every groundwater body. This lack of information is more evident in carbonatic aquifer.

The spatial variation of TEs in soil is: Al (0.22 – 7.60 mg/kg), As (0.11 – 44.87 mg/kg), Cr (4.89 – 234.40 mg/kg), Fe (0.30 – 7.24 mg/kg), Sb (0.05 – 3.59 mg/kg) and Zn (18.20 – 741.30 mg/kg), while TOC variation is 0.19 – 10.5%. The maximum concentration of these TEs and TOC are mainly located in Sierra Gorda aquifer and Sierra de las Nieves aquifer or neighboring aquifers. Both Sierra de las Nieves as Sierra Gorda show maximum precipitations; this factor can be the main reason of the values of TEs observed in that area, given that the lithology is very similar. Even more, the TOC show the maximum values too in both aquifers.

The sampling of the hydrochemistry of the groundwater in the studied are a quite scarce and limited to a few springs but some results can be highlight. Al, As, Fe and Sb show values above of WHO guidelines for drinking-water quality. Although the information is scarce, it seems that the most of high values of TEs in groundwater are linked with maximum values in soil.

The sampling carried out in Sierra Gorda aquifer shows the next characteristics:
- Al and Zn show maximum in soil and springs in the same areas.
- As, Cr and Sb must need more time in the aquifer to increase the concentration in the groundwater. Cr and Fe is in all cases under the detection limit.

The network observation of groundwater quality must to extend and the TEs analyzed. The concentration of TEs could be an argument to take into account in the carbonate aquifer classification and in the vulnerability studies. The high concentration of the TEs in soil can be a potential focus of contamination.

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Session Classification: Poster with refreshments
Track Classification: Topic 7 - Karst Hydrogeology
La Pletera salt marshes and their coastal lagoons (NE Spain) as an example of natural, and particularly hydrogeological heritage

Coastal wetlands and salt marsh areas perform a wide range of ecosystem services including shoreline stabilization, sediment and nutrient retention, high primary and secondary production, fisheries resources, habitat and food resources for terrestrial, aquatic and marine fauna, coastal water quality buffering, biomass and biodiversity reservation and recreation and tourism amenities. Consequently, these ecosystems not only show a high natural value, but also a high natural heritage value. Coastal wetlands and marsh areas may present an extraordinary value from a scientific or conservational point of view, from their natural beauty, and they may be the habitat of threatened species.

La Pletera salt marshes is a protected area located in the north of the mouth of the Ter River (NE Spain), in a region dominated by agricultural and tourism activities. These marshes are composed of wetlands and some coastal lagoons that were affected by the incomplete construction of an urban development in 1987. This area has been the focus of two LIFE+ projects, whose aim was to restore this area, to recover its ecological functionality, and to protect a threatened fish species (*Aphanius iberus*). Within these projects, a creation of a lagoon was undertaken in 2002; and in a second phase, between 2016 and 2017, four new lagoons were created.

In this area, a study to determine the importance of groundwater in these coastal lagoons has been conducted. On the one hand, hydrochemical and isotopic analyses were conducted to build hydrogeological and evaporation models. On the other one, the one-dimension model General Lake Model was used to assess the water balance and salinity dynamics in the two natural lagoons, and in the new one created in 2002.

Results show that during dry seasons groundwater maintains these ecosystems, with a 15-80% of the water in the lagoons[1]. The salinity in La Pletera lagoons depended on the mixing of fresh and sea water mainly occurring within the aquifer, and evaporation. In addition, the GLM provided us a comprehensive understanding of the hydrological dynamics, and allow us to detect that during Summer the lagoons lost water through outflows, but at the beginning of Autumn this water, saltier than the sea, returned to the lagoons in the first cyclonic storm periods[2]. Consequently, this study highlights the importance of groundwater as hydrogeological heritage, due to its role in the maintenance of the biological heritage, as well as its interest from the scientific and educational point of view.


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Session Classification: Poster with refreshments

Track Classification: Topic 6 - Groundwater, wetlands and natural heritage
Springs as elements of natural and cultural heritage. The example of Sant Hilari Sacalm (Les Guilleries, NE Spain).

Thursday, 26 September 2019 12:00 (15)

Springs are considered as elements of the natural and cultural heritage all over the world. They are part of the immaterial heritage, as a source of inspiration of legends, poems, and songs. They also present their particular architectural and hydraulic engineering structures, such as cisterns, watermills, pools, wells, water mines and reservoirs, being thus linked to the hydraulic heritage. Furthermore, springs are part of the natural heritage, including the hydrogeological one, as elements associated to groundwater and its hydrochemical characteristics. Additionally, they are ecotones, boundaries separating different ecosystems (surface and groundwater environments), which are of great importance for the distribution of aquatic fauna. In these special environments, some specialized organisms are found, making them of great value from the ecological and biological heritage point of view.

Sant Hilari Sacalm is a municipality situated in Les Guilleries Range (NE Spain), locally known as "the hundred springs town". Since the XVIII century, the economy of this town has been linked to these springs, with the settlement of distinct bottling mineral water companies, and some spas. However, some of these springs have been degraded, and even, a part of them were completely lost, due to both, human activities and natural processes.

In this context, the inter-university Chair of Water, Nature and Welfare has promoted the elaboration of a Springs Catalog, with the aim of inventorying and documenting all the springs located in Sant Hilari Sacalm, in order to: a) evaluate its conservation status, and identifying the environmental impacts that maybe affecting them; b) identify their main characteristics; c) classify the distinct springs depending on their hydraulic, hydrogeological and hydrochemical characteristics; d) collecting evidences and all the available information related to immaterial and material cultural heritage linked to these springs; and finally, e) develop a database that could be used as a catalog, and could be continuously updated.

The results of the Springs Catalog of Sant Hilari Sacalm (www.catedraaigua.cat) allowed us to identify 49 new springs, with a total of 206 records. These springs have been classified from the hydrological and hydrochemical point of view in five main groups: a) springs related to igneous weathered and fractured rocks; b) springs associated to dikes; c) springs linked to the main fault system; d) springs related to quaternary formations; and, e) artificial springs. As regards its conservation status, most of the springs showed a good or fair conservation status, but 20 of them were completely lost. From the cultural point of view, water mines, old laundry facilities, hydroelectric mills, and ponds were identified, and more than fifteen songs, legends and poems were recorded. All these results will provide Sant Hilari Sacalm with the basis to take care of, protect and promote this natural and cultural heritage.

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**Session Classification**: Parallel

**Track Classification**: Topic 6 - Groundwater, wetlands and natural heritage
Response of spring discharge to climate changes in hard rock aquifers of different lithologies

Hard rock aquifers, either sedimentary (turbidites and arenites) or igneous (ophiolites), dominate the landscape of the northern Apennines (Italy), in a climatic framework midway between subtropical mediterranean and mountainous humid. The main rainfall events occur in autumn and spring, providing an average annual precipitation between 1000 and 3000 mm/y. On the northern slope of the Apenninic chain an increased interannual variability in precipitation and temperature regime was observed in recent years with extreme droughts (e.g. in years 2012 and 2017) alternated to more rainy years, e.g. 2014 and 2018 when extreme rainfall events were concentrated over short time periods. The effects of these recharge pattern modifications on spring discharge are still mostly unknown. Exploiting the available rainfall, snowfall, air temperature and spring discharge data from the monitoring network of Emilia-Romagna region, an analysis was carried out to assess the relationship between direct aquifer recharge and the discharge of springs on a hydrologic year time scale. Discharge was monitored on 77 springs draining 44 aquifer bodies pertaining to 7 different lithologies. The relationship between recharge and discharge was determined for 3 hydrologic years that were selected based availability of monitoring data (i.e. 2010-2011, 2013-2014, 2016-2017). The 62% of the investigated aquifer bodies showed a positive correlation between aquifer recharge and spring discharge. The 19% of aquifers didn’t show a clear recharge-discharge relationship whereas the remaining 19% showed a negative correlation. Positive correlations dominate in aquifers with large recharge areas located at high elevation and characterized by extended woodland cover. From a lithologic viewpoint, the aquifers showing the most positive correlation were calcareous turbidites and arenites followed by siliciclastic turbidites. Ophiolites and fewer outcrops of dolomites and limestones did show a neutral to negative trend. The occurrence of such negative trends may be related to increased runoff due to extreme rainfall events (i.e. more than 30 mm/h) over less forested and steeper recharge areas. The overall high percent of positive trends observed between direct recharge and average spring discharge proves that changes in rainfall regime are likely to cause significant effects on spring discharges even in the short term (i.e. over a year time scale). Moreover, the modification of rainfall patterns observed in the northern Apennines (e.g. increased rainfall compared to snowfall, lower on ground permanence of snow cover, increased occurrence of extreme rainfall events) are likely to cause significant decrease of direct recharge and thus a decrease of spring discharge. The significant interannual variability of rainfall occurred in the last years provided a good platform to evaluate the effects of climate change on aquifer recharge and spring discharge. The results may be used as well to evaluate the effects of future climate changes forecasted via emissions scenarios and global circulation models.

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Session Classification: Parallel
Track Classification: Topic 2 - Groundwater and climate change
Quantifying the contributions of silicates weathering and calcite dissolution to hydrochemistry of groundwater in sandstone using Sr isotopes

Monday, 23 September 2019 17:30 (15)

In a flow system from the recharge to the corresponding discharge area, there are usually systematic changes in the hydrochemistry of groundwater. Although it is well known that silicates are the main minerals in sandstones, silicates and minor carbonates in sandstones both consume CO₂ and control of hydrochemistry of groundwater. However, it is difficult to differentiate the contribution of each type of minerals. Considering that 87Sr/86Sr ratios of water is mainly controlled by different sources, Sr isotopes of groundwater could be used to evaluate the contents of Sr derived from silicates and carbonates with different Sr isotopic compositions. In this study, it is assumed that due to the relatively abundant CO₂ in the shallow part of the aquifer, the contents and isotopes of Sr in shallow groundwater are determined by rainwater influenced by silicates weathering and carbonate dissolution. From recharge to discharge area, due to the decreased dissolved CO₂ in a closed system, the isotopes of Sr in deep groundwater are determined by shallow groundwater influenced by carbonate dissolution. The contribution of carbonates to Sr isotopes is found to be less than that of silicates in the recharge area, but outweigh that of silicates in the discharge area. The different ratios of carbonate to silicates partly explain the difference of Mg isotopes in shallow and deep groundwater in the same study area (Zhang et al., 2018).


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Session Classification : Parallel

Track Classification : Topic 5.3 - Advanced modelling tools for subsurface hydrology: from the vadose zone to deep environments
Dealing with geological heterogeneity and uncertainty in groundwater modelling: challenges and lessons learnt

Thursday, 26 September 2019 09:30 (30)

In the last decades, numerous stochastic methods have been developed and applied to deal with geological heterogeneity and uncertainty in groundwater modelling. Many studies have been published indicating the incorporating realistic geological heterogeneity and parameter and conceptual uncertainty can improve groundwater flow and solute transport simulations and decrease prediction uncertainty. Applying such methods on real world cases can however be challenging. These challenges might be the reason why such stochastic techniques have been used to a much lesser extent by practitioners than by researchers. This keynote lecture will give an overview of the current challenges and discusses new advancements to overcome them. An overview will be given of previous studies focusing on incorporating geological uncertainty through multiple-point geostatistics and on dealing with uncertainty using Bayesian approaches. The following questions will be discussed: How to build and select alternative hydrogeological conceptual models or 3D training images? Is it worth incorporating fine scale geological heterogeneity in groundwater problems or are other features (boundary conditions, data uncertainty/quality, ...) more important for improving predictions? How can stochastic methods such multiple-point geostatistics and Bayesian uncertainty assessment methods be used without suffering from very long computation times for the numerical models? Is overparametrization of groundwater models an issue in this context? What are the practical obstacles to apply stochastic methods for dealing with geological heterogeneity and uncertainty by groundwater practitioners? This talk will also summarize the lessons learnt and present recommendations for future research and for application of stochastic methods in non-academic environments for practical real-world applications.

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Session Classification : Plenary
Track Classification : Topic 5.3 - Advanced modelling tools for subsurface hydrology: from the vadose zone to deep environments
Groundwater pollution from urban and industrial liquid effluents and agriculture in the Settat aquifer (Morocco): hydrogeochemical study

Thursday, 26 September 2019 16:00 (60)

The Settat region has seen significant population growth and a major economic development through the establishment of an industrial area over the past two decades. In addition, this region is known for its agriculture which consists mostly of cereal crops (Morocco granary). This growth has been accompanied by increased rates of urban and industrial liquid effluents discharged directly in the Boumoussa River which is considered an open sewer and which has led to deterioration in the quality of the waters of this river. This situation has had an impact on the hydrodynamic behavior and groundwater quality of the Settat aquifer. To contribute to alleviate this problem, a multidisciplinary study was conducted using physicochemical analyses and analyses of stable isotopes of water. The previous studies and new analyses reveal a chemical pollution of groundwater by surface flow of the Boumoussa River. The results show an evaporation phenomenon from the groundwater, as well as the presence of irrigation return flow which mixes with the Boumoussa River to feed the aquifer.

Keywords: Groundwater flow, water chemistry, stable isotopes of water, Settat (Morocco).

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Session Classification: Poster with refreshments

Track Classification: Topic 8 - Groundwater quality and pollution processes
Experimental investigations of enhanced solute dispersion in beach aquifers due to wave action

The interface between coastal aquifers and the marine environment is an important zone controlling fluxes and processing of nutrients and carbon. To quantify these fluxes and the processes that may modify them, it is important to have a good understanding of the physical processes controlling transport and mixing at the land-ocean interface. Currently there is little experimental research on the quantitative effect of wave forcing on solute dispersion and mixing in beach aquifers. In this study we used a very large-scale (1:1) physical model experiment undertaken with a ~250 m long and 5 m wide wave flume as part of the BARDEX-II experiment (Delta flume, Deltares in Vollenhove, Netherlands) to investigate subsurface solute transport and mixing processes due to wave action within a coastal sand barrier. Specifically, relationships between ocean wave forcing and hydrodynamic solute dispersion within beach sediments were examined. The sand barrier (L=75m; H=4.5m; W=5m) was instrumented with 19 pressure transducers to measure the groundwater levels and their temporal variations. Custom designed and constructed tracer injection rigs were buried in the beach profile at two locations (2.5 and 10 meters horizontally from the mean sea level mark) to study transport and mixing processes on injected solute slugs in response to wave forcing of the beach profile. The wave forcing was controlled by a wave paddle creating waves with significant wave heights of 0.6-0.8 m and peak wave period of 8 and 12 s. Freshwater was used in the flume which eliminated the added complexity of density dependent flow and transport. Due to the stochastic nature of the wave forcing the advection and dispersion of the breakthrough curves of individual injected solute slug transport could not be analysed using analytical solutions but had to be analysed statistically. The results show that transient conditions in the beach recirculation zone due to wave run-up and beach face infiltration and hydraulic head oscillations caused by the wave forcing strongly disperse and mix subsurface solute plumes. The apparent solute dispersion due to wave forcing increased by an order of magnitude near the beach compared to the dispersion without waves (steady state and uniform flow). Our results show that beach aquifer solute transport models need to consider the enhanced dispersion to correctly quantify mixing and biogeochemical processes in this highly dynamic zone. The findings have implication for quantifying contaminant dispersion and natural attenuation as well as the natural processing and resultant fluxes of greenhouse gasses such as CO2, CH4, etc.

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Session Classification : Parallel
Track Classification: Topic 8 - Groundwater quality and pollution processes
3D complex pollutant transfer in karstified chalk aquifer systems in Eastern Normandy, France.

Thursday, 26 September 2019 17:00 (15)

Most of the chalk aquifer systems in Normandy often tend to display dual or triple porosity textures leading to complex flowfields, not easily detected through regular groundwater level measuring campaigns, which most of the time, use available unevenly distributed wells opened at different depths. This often can biased groundwater flow interpretation and lead to partially erroneous or incomplete flowfields and groundwater level maps.

These unfortunately often are used to address problems such as finding pollution sources, predicting pollutant migration, assessing plume evolution or pollutant concentration trends and setting up corrective measures to protect water resources and drinking water well fields, leading, in several cases, to partially erroneous results or only partially efficient solutions, with all sorts of technical drawbacks and negative economic impacts. This is a real problem in clean or drinking water stressed areas such chalk valleys of eastern Normandy, heavily affected by old and more recent industrial pollution.

This paper intends to discuss complex pollution transfer in two chalk aquifer valleys of eastern Normandy, where pollutants do not seem only to follow flowlines shown on available groundwater level maps. Indeed, divergent pollutant transfers also take place along fractured axes and karst conduits, which can often be associated to geological discontinuities, as previously highlighted through model calibration processes in the Avre river catchment.

In the Commerce valley case, a rare emerging pollutant - N-nitrosomopholine - was found migrating in two opposite directions a short way down from a dual source point identified in the upper Valley. This pollutant was both found south and downstream in the fractured and porous chalk aquifer, as well as way up north in a karst channel system used for drinking water purposes, in what previously was believed to be a completely different watershed.

In the Iton valley case, the pollutants are volatile organohalogenated compounds (VOH) which tend to be widespread in Normandy and often stem from historical industrial pollutions. Several potential VOH sources were identified in industrial areas in the valley south-southeast from contaminated drinking water wells; yet the groundwater flow maps suggest a southwestern origin for the pollution source(s)...

This situation often encountered in the chalk aquifer systems of eastern Normandy makes it difficult to establish "cause to effect" links between pollution sources and contaminated drinking water wells, and therefore to implement efficient corrective measures to protect drinking water well fields, and more generally water resources. To tackle this problem it is necessary to go beyond classical hydrogeological approaches. In order to achieve this and to clarify flowline interpretation, a multi-parameter approach notably based on geological and hydrogeological criteria has been developed and is discussed in this paper through the two above mentioned case studies.

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Session Classification : Parallel
Track Classification: Topic 7 - Karst Hydrogeology
GROUNDWATER MANAGEMENT: AN EXAMPLE OF A PROJECT RELTED TO REHABILITATION OF THE SOUTHERN COASTAL AQUIFER AS PART OF THE NATIONAL WATER SYSTEM IN ISRAEL

Monday, 23 September 2019 17:45 (15)

The coastal aquifer of Israel serves as one of the main water resources. It extends from Mount Carmel in the north to the Gaza Strip in the south, bounded in the west by the Mediterranean sea and in the east by mountainous formations. The average natural recharge to the aquifer is around 270 MCM/Y. It consists basically of alterations of calcareos sandstones and eolinites with clay and loam intercalations which subdivide the aquifer to four subaquifers. The aquifer is subjected to salination by seawater encroachment from the west while salination occurs also in its eastern margins through lateral flow of brackish water from eastern aquitards. In addition, the aquifer is contaminated by downward flowing pollutants related to anthropogenic domestic, industrial and agricultural activity.

Due to the continuous deterioration of the water quality and the resultant ongoing shortage of high quality water for domestic use and agriculture, a new operational and water management policy was determined. It includes a reduce of seawater encroachment from the west, and active prevention of the flow from the aquitards in the east.

The southern part of the coastal aquifer is defined as the major operative storage for the national water system as well as for local consumers. As such, maintaining its quality is especially important. However, this part is threatened by over-exploitation, and successive drought years, resulting in reduction of the storage and depletion of groundwater levels. In addition, inflow of brackish water from an aquitard along its eastern boundary, as well intensive irrigation with treated sewage water affect its quality.

In order to minimize the salination processes and allow replenishment of the storage, a rehabilitation program has been established, introducing the concept of brackish water desalination as the basic outline for rehabilitation. The two main components of this plan are:

1. “The Eastern Interceptor”, a battery of 33 production wells located along the eastern zone of the aquifer pumping 35 MCM/Y of water with salinities of 500 to 800 mg Cl/L, as raw water for desalination. This prevents the entrance of 30,000-35,000 tons of chloride per year into the western part of the southern coastal aquifer. The 30 MCM/Y of desalinated fresh water are delivered to the supply system, and the residual brine of 5 MCM/Y, are delivered to the Mediterranean Sea.

2. A balanced pumping in the western part of the aquifer, based on the annual recharge rate. This is intended to prevent the seawater from advancing to the east and salination of the aquifer.

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Session Classification: Parallel

Track Classification: Topic 1 - Groundwater assessment and management
An Agent Based Modelling approach to assess the impact of water demand in irrigation networks

Tuesday, 24 September 2019 16:00 (60)

The tragedy of the common is a dilemma often used to describe a scenario in which a group of users share a common limited pool of a certain resource. One of the most vital examples of these common pools is groundwater. In the last decades aquifers are over exploited, and about 70% of groundwater withdrawals is used for agriculture globally. Water demand management often addresses this issue with a centralized, top-down approach. Irrigation networks however, are often organized as decentralized systems, in which small farmers have access to their own well and their abstractions are difficult to monitor. One of the main problems of these kind of systems, is the achievement of sustainable use of resources with pro-active participation of all the stakeholders. A deep and comprehensive understanding of the system and the behaviour of its stakeholders is necessary for developing effective tools for sustainable water management. The objective of this study was to develop an Agent Based Modelling (ABM) tool able to simulate not only the hydro-logical aspect, but also the social and behavioural ones. This was done by designing an hybrid ABM model, which considers in the decision process of the agents both behavioural strategies and feedback from the system based on their satisfaction. Participants were introduced to a simulation game developed to obtain a better insight on the real behaviour of individuals. This study showed that a hybrid ABM model is a promising tool to analyze and manage decentralized irrigation systems. The present approach showed the capability to generate time-efficient simulations of possible agricultural scenarios and demonstrate that cooperation is vital to maintaining the sustainable levels of water resources and that communication and incentives are important factors that enhance the control and coordination of the resources. The proposed methodology matches the paradigms of the current IAHS scientific decade ‘Panta Rhei’. Since the model is highly sensitive to the behaviors of the agents, data acquisition is a necessary element for improving model performance.

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Session Classification : Poster with refreshments

Track Classification : Topic 5 - Tools, methods and models to study groundwater
Estimation of the recharge and analysis of determining factors of water stress in a karstic aquifer through a semi-aggregate model of water balance: Ezcaray-Pradoluengo Aquifer.

Tuesday, 24 September 2019 16:00 (60)

Karstic aquifers present a complex heterogeneity in their conductive and capacitive characteristics that are evident in a great spatial and temporal variability. This fact is increased in the carbonate aquifer Pradoluengo-Anguiano (La Rioja, Spain) by the action of the tectonic structures that compartmentalize it. The Oja river crosses the aquifer draining it through some springs and indirectly through a quaternary deposit of alluvial materials. This defines two blocks of the carbonate formation on both banks of the river. In a natural regime, the blocks are hydrodynamically disconnected from each other.

The water supply provides the commonwealth (Oja – Tiron) composed of 46 urban areas. The water demand will be directly satisfied by the resources of the karstic aquifer due to the presence of threats in quantity and quality of water in relation with nitrate contaminants. This is an important touristic area which has a marked seasonal variation in the number of inhabitants. The fixed population is 31,000 and rises to 46,000 approx. in the summer months. The strong seasonality of demand is accentuated by the Mediterranean climate of the region where rainfall occurs in autumn and spring and by the current evolution of the climate. The main objective of the presented study was to quantify the resources of Pradoluengo-Anguiano carbonated aquifer between 1980 and 2017. The secondary objectives were: to analyze the temporal trend of recharge and to identify annual and seasonal water stress scenarios of the aquifer. All this trying to contribute to an improvement of the water management scheme oriented to the satisfaction of the urban demand.

A numerical study was carried out with the semi-aggregate model Visual BALAN (Samper et al., 2005) to quantify the water balance (WB). This code allows the representation of the different elements of the water cycle and, particularly in this case, the recharge from snow precipitation. Numerical modeling reached all the established objectives and, possibly, has allowed the identification of some types of geological control over recharge that makes it not proportional to precipitation. The average annual recharge of the aquifer was evaluated at 5.25 hm³. In the block of the left margin (surf. = 18.12 Km2) it is 90.67% of the total recharge of the aquifer (surf. = 19.97 Km2) and in the right margin (surf. = 1.85 Km2) it is 9.33%.

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Session Classification: Poster with refreshments

Track Classification: Topic 5 - Tools, methods and models to study groundwater
Groundwater storage in conduit dominant karstic systems by Plugging Method, Susuz Springs, Seydişehir, Konya, Turkey

Susuz Spring is located on the Toros karst belt of central Turkey. In Turkish “susuz” means “without water” therefore Susuz village, as the name implies, is a village without water. Susuz Springs consist of Pınarbaşı, Yağını and Böğet springs discharging from Susuz Fault. Pınarbaşı Spring is located in a relatively lower altitude (1099 m) than the other springs i.e. Böğet (1107 m) and Yağını (1109 m) and is dry during summer (4 months). The highest recorded flow rate in Pınarbaşı spring is 8 m³/s, which was observed in 2014. There were no discharge from Böğet and Yağını springs in the springtime, although it was observed that these water points were active during storm periods. When the storm periods are taken into consideration, it is estimated that the reservoir of Susuz springs are approximately 5.5 million cubic meters. Several years ago, groundwater discharge was observed from the point of Keşdeliği (elevation:1157 m). Nowadays, due to the on-going drought for the last 10 years, groundwater drainage cannot be observed through the exploration hole. According to the long term measurements of precipitation in Seydişehir meteorological station between 1960 and 2016, the average annual rainfall is 780 mm. However, it is understood that snowfall in the meteorological stations is excluded from these measurements.

Today, the spring water is mainly utilized for irrigation, livestock production and human consumption. The springs are basically dry during summer when there is a demand especially for irrigation and livestock water requirement. The total amount of water required for the breeding of around 500 beef cattles is estimated to be around 2400 m³ for 4 months. On the other hand, the villagers need around 1000 m³ of irrigation-water during July and the total amount of the water needed is estimated as 3000 m³ for summertime.

An underground conduit system is located within the recharge zone of Susuz springs. Approximately 1.5 km of this karst system has previously been mapped by the cavers. It is estimated that the conduit system is located in the groundwater level fluctuation zone under the elevation of the maximum water level. Hydrogeological studies have been carried out on the Karst system for the last 5 years and these studies are still on-going. After completion of the hydrogeology studies in the Susuz springs, it is inevitable to perform hydrotechnical studies on the karst system. It is understood that the karst system has a conduit-dominant groundwater storage. For this reason, groundwater can be stored in the karst system by obstructing the conduit system approximately 500-1000 m behind the Susuz Fault. By plugging the individual underground conduit system, groundwater discharge can be controlled from the reserve behind the springs and, therefore it can be used throughout the year.

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Session Classification: Poster with refreshments

Track Classification: Topic 7 - Karst Hydrogeology
Groundwater storage in high Alpine catchments and sensitivity to climate change

Tuesday, 24 September 2019 12:15 (15)

High alpine areas are highly sensitive to climate change. Corresponding studies suggest a general decrease in snow accumulation and a shift of snow-influenced discharges towards earlier periods of the year, which can be combined with warm and dry summers. The magnitude of change of discharge dynamics in alpine areas will most likely be influenced by groundwater storage and its buffering capacity. However, hydrogeological data are very limited in these areas mainly because they are difficult to access during half of the year. The dynamics of alpine discharge generating processes remain therefore poorly understood.

A high alpine catchment located in the Swiss Alps has been followed during several years and the knowledge acquired by the combination of geochemical and hydrological data, geological observations and water balances allows the development of a simplified hydrogeological model. This model is then run with recent climate change scenarios for Switzerland (CH2018) to determine how groundwater will influence discharge regime changes. The link with geology will then be highlighted and the implications for water management at larger scale will be discussed.

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Session Classification: Parallel

Track Classification: Topic 2 - Groundwater and climate change
To what extent does community management ensure good functionality of groundwater supplies in rural Africa?

Monday, 23 September 2019 16:00 (60)

Within rural Africa, communal boreholes fitted with handpumps (HPBs) are likely to remain the main source of improved water supplies for decades to come. Understanding how the performance of these supplies can be improved will be central to achieving improved water security. The functionality of community HPBs relies on a range of elements which include not only groundwater resource availability, correct siting and construction of the borehole and handpump mechanism, but also equitable and enabling management arrangements.

Since the 1980s – the first UN ‘Water Decade’ – Community Based Management (CBM) has been the policy prescription par excellence for operationalising participatory development in the rural water supply sector. The cornerstone of the CBM model is the creation of a local water point committee or similar community organisation, which is charged with the operation and maintenance of the borehole. Despite its popularity and endurance, there is a relative lack of evidence on how the management capacity of communities relates to the functionality of their boreholes, and a growing recognition among development practitioners and academics that CBM of rural water supply has struggled to deliver on many of its promises.

Here we present the findings from a survey of six hundred communities across rural Ethiopia, Uganda and Malawi to examine the extent to which community water management capacity is related to borehole functionality. The capacity of water management arrangements (WMA) was assessed according to four dimensions: finance system; affordable maintenance and repair; decision making, rules, and leadership; and external support. HPB performance was assessed using a nuanced definition of borehole functionality, which captures different tiers of functionality from a simple binary ‘yes/no’ working, to capturing the level of functionality performance and reliability.

The findings reveal that whilst over two thirds of WMA are of medium to high capacity in communities, there is no strong relationship between the WMA capacity and the functionality of the borehole. Of the four management dimensions, affordable maintenance and repair was the best predictor of borehole functionality. However, the capacity of this dimension was seen to be lowest overall, with nearly two thirds of sites having weak or non-existent capacity in this respect. These findings provide evidence to support the growing claim that, in many instances, CBM by itself does not ensure improved functionality performance.

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Session Classification : Poster with refreshments
Track Classification: Topic 10 - Urban groundwater
Hydrochemical and isotopic characterization of the Tikuna Aquifer

Thursday, 26 September 2019 16:00 (60)

The Amazon Aquifer System (AAS) is the largest transboundary aquifer in South America, extending all over the Amazon region. Comprises the Alter do Chão and Solimões free aquifer subsystems and the mostly confined Tikuna aquifer subsystem (TAS). Alter do Chão and Solimões aquifers are extensively exploited, whilst TAS withdrawal is limited due to high salinity, remoteness and depth. The objective of the research is to characterize TAS recharge and discharge areas with hydrogeochemical and isotopic tools, to support the aquifer conceptual model.

TAS outcrop areas, mostly Cretaceous sandy layers, are mainly located in subandine sedimentary basins. Aquifer discharge takes place east of Purus Arch structural domain between Amazon and Solimões basins, 1800 km eastward from the main recharge area.

Collection of water samples in field campaigns in Napo and Sucumbios provinces - Ecuador, Ucayali province - Peru, Acre and Amazonas states - Brazil was ensued by chemical and isotopic analyses of major ions, oxygen-18, deuterium, tritium, carbon-13 and carbon-14.

Western border Cretaceous recharge areas of Napo and Sucumbios province present a slightly mineralized HCO₃-Ca recent water. Oxygen-18 and deuterium isotopic signatures are similar to the local meteoric line, with some altitude effect. Tritium and Carbon-14 dating confirmed those waters are recent. In Ucayali Province, high Na-Cl mineralized springs reach temperatures up to 90 °C. Hot springs’ oxygen-18 and deuterium contents show slight depletion as compared to local shallow waters. Carbon-14 age indicated groundwater approximately 20,000 years B.P., with tritium below detection limit. Finally, in Serra do Divisor-Acre, HCO₃-Ca groundwater type has an oxygen-18 and deuterium concentration somewhat similar to Ucayali province, with a discrete depletion of heavy isotopes in older waters. Carbon-14 dating of Cretaceous waters indicated ages ca. 6,000 years B.P. and absence of tritium.

The Purus geological arch area, western of Manaus, is a transition zone between confined and free aquifer conditions. In this zone, a mixed water type is observed in the research wells. Oxygen-18 and deuterium concentrations vary along the local meteoric line, but represent a weighted average of rainwater in the region. Tritium values were null, except for one well tapping shallow waters. Carbon-14 ages ranged between 100 to 22,000 years B.P., generally increasing with depth. These results point to the occurrence of a discharging area, with a mixing pattern between young and older waters.

The presence of older waters in supposedly recharge areas indicate intermediary aquifer outflows along the TAS flow lines from west to east. Discharge areas, in the east border of the aquifer system are mixed with younger waters from shallow aquifers after deconfinement, due to the local high precipitation rates.

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**Session Classification:** Poster with refreshments

**Track Classification:** Topic 9 - Groundwater and socio-economic development in Latin-America
Groundwater, water-security and sustainable livelihoods

Tuesday, 24 September 2019 09:30 (30)

For many parts of the world, the development of groundwater increases water security and can lead to more sustainable livelihoods and a reduction in poverty. This is particularly the case for Africa and South Asia where water insecurity is endemic. This talk will explore: (1) water security in rural Africa particularly throughout drought condition and the interlinking factors influencing the functionality and reliability of groundwater supplies; (2) the benefits of having a reliable groundwater supply; (3) the potential across Africa for higher yielding supplies both for urban supply and irrigation; and (4) water security in South Asia given high abstraction for agricultural and urban use. The discussions will be framed by the high pace of global environmental change and the challenges of governing groundwater development.

Drawing on 25 years of research funded mainly by the UK Department for International Development the talk will be illustrated by recent results from the ongoing UK/Africa research programme, UPGro (unlocking the potential of groundwater for the poor), and various South Asian / UK research partnerships on the Indo-Gangetic Basin and Peninsular India.

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Session Classification: Plenary
Track Classification: Topic 3.1 - Groundwater and water security in developing countries
Rare Earth Elements in thermal and mineral waters from Mesozoic aquifers of the Polish Lowlands

Monday, 23 September 2019 16:00 (60)

Chemical composition including rare earth elements (REEs) was determined in thermal and mineral water samples collected from 33 spa and geothermal wells located in the Polish Lowlands (northern and central Poland). REE examinations have not been performed for this kind of thermal and medicinal mineral waters in Poland so far.

Observation covered the Mesozoic aquifers, built mainly of Jurassic and less often Triassic or Cretaceous sandstone series, which occur at the depth ranging from 20 to 2,500 m below land surface. Selected elements in filtered (0.45 µm) and acidified (HNO3) water samples were determined by inductively coupled plasma optical emission spectrometry (ICP-OES) and inductively coupled plasma mass spectrometry (ICP-MS) methods with the use of Sea-Fast preconcentration tool.

The examined waters, characterized by TDS value ranging from several to 114 g/L, represent mainly Na-Cl type and much less common HCO3 or SO4 types. The Cl ion concentration changes from 16.5 mg/l to 71,100 mg/l. The highest water temperature value 89 °C was measured at the well head in the Stargard geothermal plant, NW Poland.

Total rare earth elements (La, Ce, Pr, Nd, Sm, Eu, Gd, Tb, Dy, Ho, Er, Yb, Lu) concentration in groundwater samples changes from 0.06 to 59.9 ng/L, with the average being value 13.3 ng/L. Yttrium content ranges from 0.84 to 54.5 ng/L with the average being value 14.9 ng/L. In most of the water samples the ∑REE value is lower than 10 ng/L. Within the presented data population, ∑REE concentration as well as concentrations of individual REEs values display no clear correlation with basic physical and chemical parameters of the examined waters, such as pH, TDS, temperature and depth of occurrence.

The obtained REE results normalized to European Shale allowed for describing 6 general types of REE fractionation patterns, expressing relation between 3 groups of the REEs: light (LREE: La-Nd), middle (MREE: Sm-Dy) and heavy (HREE: Ho-Lu). The following REE patterns were distinguished:

1) LREE < MREE < HREE - described for waters from most of the examined wells;
2) LREE < MREE > HREE - frequent;
3) LREE = MREE < HREE; 4) LREE > MREE > HREE; 5) LREE < MREE = HREE;
6) LREE = MREE > HREE. REE patterns of 3-6 types are less frequent.

When we apply the division into two groups: (HREE: La-Eu) and LREE (Gd-Lu), we can notice a distinct quantitative advantage of HREE over LREE in the examined water samples. This is usually explained by the fact that LREE display a stronger tendency than HREE to be absorbed by sediment particles. The development of this process is favored by a long residence time typical of waters in deep seated aquifers.

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Session Classification: Poster with refreshments

Track Classification: Topic 5.3 - Advanced modelling tools for subsurface hydrology: from the vadose zone to deep environments
Impact of chalk karst on river flow in Normandy: comparison of the behavior of three rivers and quantification of karst flow

Thursday, 26 September 2019 17:15 (15)

In 1758, Jean-Etienne Guettard mentioned in a publication of the French Royal Academy of Sciences the particular behavior of three rivers in Normandy that “gradually disappear and then reappear downstream”. Guettard noticed “holes in the river bed that absorb river flow”. These three rivers are respectfully the Iton, the Avre and the Risle rivers, all flowing on the Upper Cretaceous chalk, and located in the eastern part of Normandy, in northwest France.

The Risle and Avre rivers are both constituted of 3 segments showing changing hydraulic behaviors: a first section upstream where the river and the groundwater (GW) are hydraulically connected and are in equilibrium, a middle portion where the river and the GW are disconnected, with sinkholes forming in the minor bed, progressively decreasing the river flowrate and sometimes leading to complete river dry up, and a third section downstream, representing converging outlets of the karst aquifer system, where river and GW undergo reconnection, starting up with a strong resurgence area. The Iton river is a more complex hydrosystem with two successive karst sections resulting in five segments showing changing hydraulic behaviors (river and WT level being alternatively connected and disconnected).

Several monitoring networks for groundwater level and flowrate do exist in these rivers since the seventies or eighties. A more dense and better located monitoring network was implemented in the Risle river basin as part of the Risle Observatory which operated over a 3 year period (2013-2016).

These monitoring networks allowed for using lumped hydrological modelling with GARDENIA to notably quantify groundwater karstic flowrate as well as the groundwater components of the river flow.

Eleven (11) lumped modelling processes were carried out with calibration using both piezometric levels and riverflow: 2 models were generated in the Iton basin, 4 in the Risle basin and 3 in the Avre basin. Two (2) other models were also elaborated in less karstic chalk basins (Austreberthe and Cailly Rivers) for comparison.

Regarding the groundwater component of the river flow, results obtained showed that for less karstic chalk basins, the average net GW input accounts for 74% to 98% of the mean river flow. In karstic basins, the net groundwater component of the mean river flow can decrease to around 30% at the end of the karst sections (i.e: 34% for the Risle and 29% for the Avre). In the karst sections of the rivers, GW karst flow can be highly significant, up to 36% of the effective rainfall in the second karst segment of the Iton river and 56% in the middle portion of the Risle river).

Acquiring a good understanding of these GW and river flow interaction processes is essential for floodrisk assessment in karstic chalk environments.

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Session Classification: Parallel

Track Classification: Topic 7 - Karst Hydrogeology
Assessing the feasibility of managed aquifer recharge through unsaturated zone modeling with VS2DTI in a multilayer system

Monday, 23 September 2019 18:00 (15)

Managed Aquifer Recharge (MAR) can play an important role as a measure to control over-abstraction and to restore the groundwater balance under climate change scenarios. MAR may also be applied to sustain or improve the functioning of ecosystems. One of the major difficulties in evaluating the applicability of MAR is to model the infiltration process through variably saturated media with the presence of perched aquifers in alluvial systems. This is the case of the Medina del Campo groundwater basin within the Duero River basin.

In this study, we apply the unsaturated finite difference flow code VS2DTI to simulate MAR to the deep aquifer system used for groundwater exploitation. We estimated average natural recharge for a typical 10-year distribution of wet, medium and dry years based on the data of the period 1940-2010. Eight textural layers with their corresponding hydraulic parameters (saturated hydraulic conductivity, specific storage, porosity, residual moisture content, and alpha and beta van Genuchten parameters) were defined according to reference values in a 2000 m x 55.5 m axisymmetric rectangular domain. A variable grid with increasing cell size from the top left corner (MAR point) was specified. In the top boundary, artificial recharge was simulated as a constant specified flow condition through a 4 m riverbed in the top left corner and natural recharge was evenly distributed along the 2000 m of this boundary. A constant pressure head (p=0) was used to define the deep groundwater level in the bottom boundary. We used flow source points as a Neumann type boundary condition inside the domain to simulate the top aquifer located between 2 m and 11 m deep. The amount of flow in these points as well as the initial moisture conditions were derived from the steady flow model.

The average volume of available water for MAR as estimated by the Duero basin Water Authority was set to 0.3 m/d and distributed proportionally as a function of average annual precipitation for each type of year. For wet years, MAR equaled 0.4 m/d, 0.3 m/d for medium years, and 0 during dry years. A sensitivity analysis of the hydraulic parameters was also carried out.

The results show low water balance errors in the simulations (< 2%) and that the MAR is inefficient to recharge the deeper aquifer due to the low transmissivity and water retention capacity of the aquitard underneath the top aquifer. The main interest of the proposed approach is that it provides a basis for simple assessment of MAR feasibility through unsaturated flow modeling. This is an important contribution since multilayer aquifer systems where there are perched aquifers are difficult to tackle with standard saturated groundwater flow programs.

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Session Classification : Parallel
Track Classification: Topic 5.3 - Advanced modelling tools for subsurface hydrology: from the vadose zone to deep environments
New insights on groundwater recharge processes in the Andean piedmont of Northern Chile and impact on groundwater resources management.

Main aquifers of Northern Chile have been declared restricted areas thus no more water right can be granted. The situation gives rise to conflicts between groundwater users - i.e. mines, water supply, agriculture and Native American communities – as well as claims and general perception of water scarcity and groundwater overexploitation. This situation has motivated recent research works on the Pampa del Tamarugal regional aquifer, located in the Region of Tarapaca, Northern part of the Atacama Desert in Chile. A closer look at available data and technical information used to justify the declaration of restriction in 2009 shows bias in the groundwater availability estimation as well as errors and uncertainties on all the terms of the groundwater balance and limits definition. Recent research works show that the Pampa del Tamarugal aquifer surface and volume is much higher than initially estimated. The demonstrated continuity of Cenozoic formations and associated groundwater flows pushes the boundaries of the aquifer tens of kilometres towards the east within the Piedmont area, except where the presence of Mesozoic basement heights, which exerts a prominent control over the spatial distribution of the Cenozoic cover. The works show also that the main recharge takes place at the contact between the river and the Cenozoic cover, at the apex of alluvial fans. The generation of new data in the Oasis of Pica, through the exploration and geological and hydrogeological study of underground filtration galleries, confirms these findings and unveils others. The identification of different types of underground springs, their hydrochemical and water stable isotopes content analysis, analysed along with already existing data, allow the identification of groundwater circulations within the Mesozoic basement. Those circulations constitute a significant contribution to the Pica Oasis and Pampa del Tamarugal aquifer recharge. They also reveal groundwater circulation between catchments on the western slope of the Precordillera. No circulations had been identified between the Altiplano and the Oasis of Pica although recharge from the Mesozoic basement to Pampa del Tamarugal aquifer can be seriously considered and further research is needed. Those findings, along with the moderate decrease of groundwater levels in the PdT aquifer (less than 10 cm/year over an aquifer depth of few hundred meters) support the fact that the PdT aquifer is not severely overexploited. The lack of information on water resources justified the declaration of restriction and generated a status quo situation where the actors involved in the aquifer management pursue their own strategies, and uses water management and the information available for these purposes. The generation of scientific information has not been able to break this status quo. As a result, many small users are excluded of access to and management of groundwater.

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Session Classification : Poster with refreshments
Track Classification: Topic 9 - Groundwater and socio-economic development in Latin-America
Use of local knowledge and participative monitoring in scarce data areas. Case of the hyperarid and mountainous Northern Chile

In arid and mountainous regions, the elaboration of conceptual and numerical hydrogeological models requires a large amount of data due to the temporal and spatial heterogeneity of hydrometeorological variables. The convective characteristic of rainfall lead to highly localized precipitation events, heterogeneous in space and time and strongly influenced by topographic and orographic patterns. Most existing observational networks in those regions do not adequately capture the variability of the precipitation, as they tend to be sparse and sample only locations that are relatively accessible and at low altitudes. Furthermore, streamflow monitoring is particularly challenging. The hydrologic regime and stream morphology are characterized by low, ephemeral or intermittent flows with changing gullies in very wide cross sections shaped by flash floods. Inter-annual variability is extremely high. North Chile is one of the world’s most arid areas with extremely high elevation differences from the sea level up to 6000 m. a.s.l. in the Andean Cordillera. Since the onset of large mining projects in the nineties, constant population and economic growth generates high pressure on water resources. The existing official hydrometric network allows for the description of general characteristics and trends at national level, but not at lower scale. Thus, how to characterize the water resources of basins without historical data? The region of Tarapacá is inhabited by Aymara communities, a Native American ancestral tribe. They resort to a great diversity of indicators to predict the climate and understand natural processes as the result of a millennial observation of nature. We propose two ways for the generation of hydrological data relying on local people: i. use of the ancestral knowledge, and ii. Participatory monitoring of water resources. The use of ancestral knowledge allowed the valorisation of historical unregistered information, i.e. localize water points, identify areas of importance to monitor water resources, reconstitute the historical flow behaviour. It produces qualitative data that needs to be validated and “translated” into scientific language. The participatory monitoring allowed the generation of data in hard-to-reach remote and mountainous areas, i.e. precipitation, piezometric level, flow, physicochemical parameters. It produces quantitative data in areas that are difficult to access and/or without possibility of installing equipment. The generated information allow to build the hydrogeological conceptual model. Additionally, the participatory monitoring of water resources evolved from being a monitoring tool to a development tool. Over time, the data and information generated were useful to improve and adapt agricultural activities, understand the processes that occur in the basin, integrate local knowledge to scientific knowledge and place communities as relevant actors in the basin. With their continuous presence in the field, they can raise the information in a valid way for the rest of the actors.

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Session Classification : Poster with refreshments
Track Classification: Topic 5 - Tools, methods and models to study groundwater
Karst groundwater flow processes is difficult to estimate due to heterogeneity of aqueous media. This paper, taken Fangshan, the southeast of Beijing, as the research area. In order to improve the understanding of groundwater evolution in Fangshan karst groundwatre system, hydrochemical and isotopic data were sampled in the Xiayunling-Longmentai synclinorium hydrogeological unit and analysed as indicators for conceptual model to identify the origins of groundwater, hydrogeochemical evolution and the geological structure effects. The results show that: groundwater mainly originates from the local rainfall, hydrochemical types of which are mainly HCO3-Ca·Mg and almost unchanged with time. The origin of primary chemical components is associated with dissolution and precipitation of aquifer minerals, including calcium carbonate, dolomite, and gypsum. From the northwest and northeast mountain regions to the piedmont zone in the southeast, δ18O and δD of groundwater generally showed an increasing trend. For the hydrochemical origin, the mineral composition of groundwater should be accumulated from the mountain to piedmont region. The geological structure could control karst groundwater flow system and has effects on TDS and Sr2+ content. TDS rises gradually with runoff distance as a whole. In addition, the groundwater nearby Dayugou fault(F21) and southern discharge area have a lower TDS value than that in the surrounding area. This could be the result of groundwater flow at the different geological structure, causing various residence time and interactions between groundwater and aquifer minerals. The intrusive rocks are rich in Sr elements. The groundwater samples investigated neighboring lamprophyre (χ) and magmatic rock (γ), have higher Sr2+ concentrations compared with those from other flow fields. Additionally, anthropogenic activities such as rising exploitation and the usage of ammonium chloride fertilizer also have striking effects on hydrochemical components. This research could provide significant insights into the local governments that can make effective management and protection of karst groundwater in Beijing.

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Session Classification : Parallel

Track Classification : Topic 7 - Karst Hydrogeology
Study of a coastal aquifer under the oceanic influence: case of Nouakchott (Mauritania)

Tuesday, 24 September 2019 16:00 (60)

The present study is based, on the one hand, on the water level fluctuations observation and analysis in the Quaternary aquifer of Nouakchott (Mauritania) and, on the other hand, on a comparison of these variations with those of oceanic tide and rainfall. The piezometric network data shows that the flow is from the west to the southeast of the city with the presence of a dome in the center of city (PZ3AX5E5) where the piezometric level is 0.8 m.

Recordings were made on a piezometer located 630 m from the coast. Data were collected between July 2017 and July 2018 due to one measurement every two hours. The results showed a tide influence on the water level in the piezometers. We observe that variations in groundwater level simultaneously follow the fluctuations of the ocean. Records show an increase of 0.40m water level for a tide of 1.88 m. The influence of the tides contributes to water table rise under the city of Nouakchott, already saturated by the losses of water pipes, the domestic discharges and the rains.

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Session Classification : Poster with refreshments

Track Classification : Topic 10 - Urban groundwater
Quantification of groundwater recharge is one of the most important tasks in hydrogeology. Many methods of recharge estimation, which can be applied in various spatial and time scales, have been proposed. The main goal of the present work is to identify groundwater recharge at an experimental site on an outwash plain, using different techniques: analysis of water table fluctuations, field tracer experiment and numerical modeling of the unsaturated zone flow.

The study area is located in Bory Tucholskie region in northern Poland. It represents a typical outwash plain setting, dominated by fluvio-glacial sands with locally occurring clay layers and lenses. The depth to groundwater table is about 6 to 10 m. Continuous measurements of weather data, soil water content, electric conductivity and groundwater table position have been carried out at the site since April 2017. Water content in the vadose zone is measured in four soil profiles, at four depths in each profile. In order to capture the influence of vegetation cover, two profiles were located on open grassland and two in pine forest. The tracer experiments were carried out in two profiles as pulse injections of chlorides applied on the ground surface. The sensors of electric conductivity placed at various depths allowed to track the tracer. Monitoring wells were installed close to each of the four profiles, in order to measure groundwater level and electric conductivity in the saturated zone. The measured range of fluctuations of groundwater table was 0.4 to 0.75 m. Numerical simulations of flow in the vadose zone were carried out using HYDRUS-1D computer program, based on one-dimensional form of the Richards equation. In this work we will present a comparison of the results obtained from the analysis of water table fluctuations, tracer tests and numerical modeling. The preliminary results show that groundwater recharge in the investigation area is about 75 to 130 mm/year.

The work is funded by National Science Centre (NCN), Poland (grant 2015/17/B/ST10/03233 "Groundwater recharge on outwash plain").
Permeability of the crystalline basement in Uganda - evidence from approximately 600 pumping tests and implications for solar pumping

Monday, 23 September 2019 17:30 (15)

Crystalline basement rocks of Precambrian age underlie nearly three quarters of Uganda, providing groundwater supplies to meet ever increasing demand from rural areas and urban growth centres. Development of groundwater sources is commonly based on several factors including physical and socio-economic considerations that have a bearing on their functionality and long term reliability. Here we present new transmissivity data from >600 boreholes across basement aquifers in Uganda calculated from previously unanalyzed pumping test data. Other data are available to help interpret the transmissivity values, including borehole lithological logs, weathering thickness, well design and depth to groundwater. Spatial and depth comparisons are made to relate aquifer permeability to lithology and weathering, and also to relate borehole yields to well design. The data provide an improved understanding of the physical permeability of weathered crystalline basement rock aquifers across Uganda, complimenting earlier studies of vertical permeability profiles in focused areas. The analysis helps inform the physical capacity of the aquifer to supply the borehole yields to meet increasing demands, and application potential for higher abstraction technologies, such as solar pumps.

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Session Classification : Parallel

Track Classification : Topic 1 - Groundwater assessment and management
Groundwater management in highly intervened aquifers is a challenge for environmental authorities that seek the medium and long-term sustainability of the resource. Climate change and socio-economic developments exacerbate the situation and provide water authorities with increasingly complex problematics.

This study is focused on the Valle del Cauca aquifer, Colombia, which is of great importance for the region since groundwater is intensively used for agriculture, industry and also as an option to supply drinking water to the inhabitants of Santiago de Cali, the third largest city of Colombia, and to other municipalities located in the valley.

A multi-scale groundwater numerical modelling tool has been developed to study the processes occurring in the aquifer, through the use of numerical models at various scales. The tool supports the development of the aquifer management plans, which are formulated by the regional environmental authorities: CVC for the regional aquifer and DAGMA for the urban area of Santiago de Cali. The objective of the management plans is to update the knowledge on the groundwater system and to formulate strategies to address problematics and conflicts on the use of groundwater resources.

The regional processes were studied at the largest scale (resolution of 100 by 100 meters), through a regional numerical model that covers the area of interest in Valle del Cauca. This model was developed in three phases, in which sub-regional models were developed, and boundary conditions were defined to allow coupling of the models. A detailed model was developed for Santiago de Cali, with a resolution of 25 by 25 meters. This model includes specific processes associated with the urban area, such as effects of urbanisation on groundwater recharge, drainage and artificial recharge through water supply sewage pipes, intense shallow groundwater pumping for infrastructure drainage, etc. The regional model was used to define the boundary conditions of the detailed urban model.

The tool was developed with the active participation of CVC and DAGMA, thus ensuring that it responds to the particular needs of the environmental authorities.

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**Session Classification**: Parallel

**Track Classification**: Topic 5.4 - Innovative approaches for understanding groundwater
flow systems
Is current groundwater development in Ergene River Basin (North-western Turkey) sustainable?

Monday, 23 September 2019 16:00 (60)

Ergene River Basin is a part of the Thracian Basin with its drainage area of 11300 km2. The Pliocene aged Sandy Complex aquifer (SCA), enrobing about half of the Ergene River basin, is a regional aquifer. It is tapped by several thousand wells, mainly for irrigation use. The eastern and western parts of the SCA is unconfined while the central part is confined. The saturated thickness of this spoon-shaped aquifer reaches the maximum value (350 m) in the central part. The Çorlu-Lüleburgaz fault interrupts the continuity of the SCA by acting as a barrier in the artesian area. SCA has experienced extreme declines in groundwater levels since the 1970s (70 m in the last 46 years). The persistent declines in groundwater levels in the SCA drew the attention of many researchers and a groundwater flow model was constructed to determine the safe and sustainable yields and the limits of utilization for the SCA (Ökten and Yazıcıgil, 2005). This model was first calibrated under steady-state and transient conditions and, eventually, tested a total of eight alternative groundwater pumping scenarios (from 2001 to 2030) to predict both groundwater level and reserve changes in the aquifer system along with the average base flow to streams. In one of these scenarios (A), Ökten and Yazıcıgil (2005) continued the pumpage conditions of the year 2000, for the rest of the scenarios, they decreased the annual pumping rates to be equal to 100%, 90%, 80%, 70%, 60% and 45% of the annual recharge rates, respectively. Eventually, they found out that the average decline in groundwater levels is between 28 m (Scenario A) and -3.9 m (Scenario G). This study is carried out to examine the current groundwater levels in the SCA by using five selected observation wells with limnigraphs. Accordingly, the groundwater levels obtained through 8 different scenarios are compared with the actual groundwater levels from January 2001 to September 2018. The results showed that the current pumping rates are greater than both the sustainable and safe yields of the system. In fact, in two wells, the groundwater levels are even below the levels estimated by Scenario A and in two of them, the levels are similar to the ones obtained as a result of Scenario B. These comparison efforts suggest that, sustainable groundwater management policies and plans have not been adopted in the area. The pumping rates over the past 18 years were significantly greater than the sustainable yield (168 hm3/year) and traditionally defined safe-yield in Turkey (about 70% of the annual recharge, 261hm3/year), causing significant declines in groundwater levels and base flow of the streams.


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Session Classification : Poster with refreshments

Track Classification : Topic 3 - Groundwater sustainability and governance
THE ARTIFICIAL RECHARGE OF AN URBAN DRINKING WATER AQUIFER (Udine – Italy): A DIGITAL MODEL TO GROW THE WATER FLOW FROM WELLS, PROJECT THE POLLUTION PROTECTION WORKS, OPTIMIZE THE COST-BENEFITS

Monday, 23 September 2019 11:30 (15)

THE PROBLEM

The drinking water system (AMGA public supply company) for UDINE city (Italy) is alimented by a freatic aquifer placed near the Torre River and a pumping field (surface 1km²). These groundwaters and the entire drinking water system (150,000 people) are menaced by 2 problems:
1. a big decrease of piezometric levels during the summer periods (4 months/year) which forces AMGA to buy drinking water from concurrent aqueducts, paying an exagerate cost;
2. the quality of groundwaters are constantly menaced by pollution from accidental events including chemical industrial end agriculture pollution, bad human acts against strategic water ressources.

The solution was to find the best artificial recharge works to grow the piezometric heads in the aquifer, to produce an increase of water flow pumped from AMGA aquifer, to guarantee during the summer a sufficient water supply for UDINE.

THE RESULTS

Starting from hydrogeologic numerical model for the analysys of several different options and test for calculate the recharge strategy, we found the optimal solution to build modifications in the pumping field, new hydraulic drainage works, to find the project parameters-geometry-dimensions, to find the optimized costs which eliminated all the other solutions tested by model.

The results gave:
1. type of works and governance actions to increase pumped water flow from aquifer, to increase the piezometric level and the drinking water availability during summer seasons:
   - 2 barrages in the river, 1 artificial recharge basin;
   - growth of the average piezometric head in the pumping field = 0.6m;
   - increase of pumping flow = 120 l/s in the summer season;
   - cost savings on purchasing water from drinking water company competitor= 1 €/m³= 620.000€/year;
   - gross pay back = 5 years;
   - Cost = € 2.4 million.
2. type of works and governance actions to prevent groundwater pollution crisis:
   - installations to control the quality of water starting from the artificial recharge sources;
   - n.7 monitoring piezometers placed in hydrogeologic optimized positions;
   - arriving time of a worst possible water pollution plus intervention = 9 days;
   - imposed frequence and time to complete laboratory analysis sets = 9 days;
   - project of the alarm system h24 placed in the aqueduct UDINE center placed 20km from the pumping field;
   - preparation of a intervention procedure and field equipment in case of water pollution crisis/emergency (diffuse, punctual, external aggression, critical events).
3. this method can to be applied in every freatic drinking water aquifer with a recharge source available nearby.
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Session Classification : Parallel

Track Classification : Topic 3 - Groundwater sustainability and governance
The sustainability of non-renewable groundwater from Guarani Aquifer System – A case study in a city at São Paulo State, Brazil

Monday, 23 September 2019 16:00 (60)

The Guarani Aquifer (SAG) in South America is a huge hydrogeological system that underlies an area of about 1,100,000 km², mainly distributed in Brazil (62%), Paraguay, Uruguay and Argentina, is composed by a sequence of sandstone beds, mainly weakly-cemented, of Triassic-Jurassic age, formed by the processes of continental deposition (aeolic, fluvial and lacustrine). The average thickness is about 250 m, varying from < 50m to > 600m, and reaches depths of over 1,000 m (Foster et al., 2009).

The west of São Paulo State - Brazil, where is localized the study area, has a huge dependency on groundwater resources, since the surface water resources are distant from the urban centers. Around the Marilia municipality, within an area of approximately 800 km², there are nine pumping wells in the SAG. The Marilia municipality, the biggest city at the study area, is supplied by SAG with 1,300 m³/h (33,3% of the total water resources), with five pumping wells.

In this region, the average thickness of SAG is about 218 m, with minimum of 180 m and maximum of 254 m, and the thickness of basalt varies between 564 and 785 m. This portion of SAG belongs to the IV resource management zone classified by Foster et al. (2009) as "Deep Confined Zone", where pumped groundwater is being 'mined' from aquifer storage with continuously (but very gradually) falling potentiometric surface. Prandi et al. (2013) identified residual drawdown varying between 48 a 59.5 m in three of the SAG pumping wells located at Marilia since 1990.

Within this scenario, five SAG's pumping wells were monitored for two years with the objective to measure the variation of the groundwater level with the pumping schemes. The activities developed consisted by the preparation of a database, well selection and installation of the monitoring equipments, download the monitoring data, consolidation and interpretation of data, and management recommendations were given.

Besides of many problems during the two years monitoring, some results could be described. The SAG drawdown is happening at the region and still in course. In approximately twenty years, the potenctiometric surface decline at maximum 60 m. The hydraulic gradient between the pumping wells is lower in comparison with at the beginning of the pumping, and bigger between these pumping wells and other closest confined SAG wells.

Considering that the SAG is a transboundary aquifer and the west of São Paulo State is very dependent of groundwater resources, this region demands a consistent and constant monitoring program. The aquifer system characterization (quantification of aquifer storage reserves – specific yields, assessment of contemporary recharge rates and appraisal of depletion trends) to provide adequate predictions is essential (Lloyd,1999) to define restriction areas and control of abstraction and use of groundwater.

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The sustainability of non- ...
Climate Change Effects on Groundwater: Expectations and Observations

Tuesday, 24 September 2019 10:00 (30)

Groundwater storage fluctuates more slowly than the near-surface, non-frozen components of terrestrial water storage (soil moisture and surface waters), but because of its larger range of variability it is often more indicative of long period climate changes. Hindering groundwater’s use as an indicator of water cycle and climate variability is the paucity of long term, continuous measurement records that are publicly available. Further, it is challenging to distinguish climate change impacts on groundwater levels from natural variability and direct anthropogenic effects. In this presentation we will review the current state of understanding of how climate change is influencing or could potentially influence groundwater recharge and storage. We will also quantify and attribute apparent trends in terrestrial water storage observed worldwide by the NASA/German Gravity Recovery and Climate Experiment (GRACE) satellite mission during 2002-2016. Many of the apparent trends were dominated by groundwater storage variations, and climate change appears to be a factor in some cases. In particular, water storage increases in northern Eurasia and Canada and decreases in northern Africa and southern Asia are consistent with climate model predictions.

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Session Classification : Plenary

Track Classification : Topic 2 - Groundwater and climate change
HYDROLOGIC AND STRATIGRAPHIC IMPACTS TO DENSITY-DRIVEN FLOW ALONG BRINE-TO-FRESHWATER INTERFACES IN ARID BASINS

Thursday, 26 September 2019 12:15 (15)

Density-dependent flow occurs in areas where high-salinity, denser groundwater interacts with low-salinity and less dense groundwater to create a brine-to-freshwater interface. Northern Chile’s Salar de Atacama (SdA) exhibits an exceptionally shallow interface when compared to previous density-driven modeling attempts of the basin. We therefore investigate the impact of subsurface heterogeneity on an interface’s geometry and response to changes in recharge. Site-specific 2-D models of the interface in the southeastern region of SdA, with interpretations of the area’s hydrostratigraphic framework, provide an analysis for the density-driven flow that influences the geometry of the brine-to-freshwater interface that has developed in the region. A separate equally probable series of distributions of hydraulic conductivity using a geostatistical approach is based on geologic core data from SdA and provides a means for expanding analysis to other similar arid salar (“salt flat”) environments. The study includes three groups of realizations of hydraulic conductivity distribution with 50 realizations in each group. Each group varies in the length of continuity of hydrostratigraphic units, with equal continuity between the horizontal and vertical directions in the first, increased horizontal continuity by a factor of two in the second group, and increased horizontal continuity by a factor of three in the third. Changes in hydrologic conditions are introduced to each realization and the interface’s response is subsequently assessed. Metrics for evaluation include migration rate, change in the interface’s areal extent, change in interface slope, and the response rate following the introduction to a perturbation in the aquifer’s hydrology. Model analyses indicate that evaporation rates decrease the interface’s dip and sensitivity despite changes in hydrologic and geologic conditions. Increased continuity of high-permeability pathways also decreases interface slope; increasing continuity also decreases interface stability in terms of time required to reach a new steady state. These results suggest that subsurface heterogeneity is an important but often overlooked aquifer characteristic for simulating and predicting saline intrusion risks.

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Session Classification : Parallel

Track Classification : Topic 5 - Tools, methods and models to study groundwater
Characterization of the regional groundwater flow system and groundwater related phenomena in the Villány thermal karst area (Hungary)

Thursday, 26 September 2019 17:30 (15)

In South Transdanubia (Hungary) there are remarkable geothermal and hydrocarbon resources. Besides the sedimentary basin, the area also includes the Villány Thermal Karst. The karst area is characterized by natural thermal water discharge at the boundary of outcropping carbonate hills and the sedimentary basin, which established the thermal water exploration of Hungary in 1866. These regional discharge areas are favourable sites of hypogenic caves as well. These geofluid systems and groundwater related phenomena are usually investigated separately and their interactions are just neglected. The aim of this study was to give all these resources and phenomena a common framework applying the dynamic system approach and complete the regional hydraulic and hydro-geochemical assessment of the area. During the measured data based hydraulic assessment pressure-elevation (p(z)) profiles, tomographic fluid potential maps and hydraulic cross sections had been constructed to determine the vertical and horizontal fluid flow conditions. The hydrochemical study (concentration- and temperature-elevation profiles, concentration map series) helped to understand the geofluid systems more accurately. Local scale studies focused on groundwater related phenomena: on the research of a spring lake and a hypogenic cave. With geophysical measurements the local geological build-up of the spring lake was explored. Time series of physico-chemical parameters of the spring and in the cave help to understand the local scale dynamics of the system which was verified by numerical simulation. In-situ experiment using carbonate rock slices combined with continuous recording of the physico-chemical parameters reported on the recent processes in the cave.

The National Research, Development and Innovation Fund has provided financial support to the research under the grant agreement no. PD 116227.

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Session Classification: Parallel

Track Classification: Topic 7 - Karst Hydrogeology
Investigation of groundwater recharge under a semiarid irrigated mountain-front area (Haouz-Tensift basin, Morocco).

High elevation mountains often constitute water supplier to arid and semiarid adjacent areas. Indeed, a significant component of groundwater recharge to alluvial aquifer of basin floor potentially originates from mountain ranges and is known as Mountain Front Recharge. The latter may involve various processes (stream losses, subsurface flow from the mountain block, direct infiltration from rainfall, etc.). In the Haouz-Tensift basin, central Morocco, the High-Atlas Mountains are often referred to as the water tower (600 mm as average precipitation) for the Haouz plain (precipitation of 250 mm). Groundwater recharge processes in the area are still poorly documented and need to be well understood and assessed for a better management of groundwater already experiencing severe depletion. To this objective, stable isotopes (18O and 2H) and major ions were used. Precipitation (rainfall and snow), wells, springs and streamflow were sampled in September 2017 (dry season) and March 2018 (wet season). Results have shown that in addition to streamflow losses and subsurface inflow from the mountain front, surface water leakage beneath irrigated crops contributed mainly to groundwater recharge. The irrigation practices and the traditional irrigation regime are likely to generate significant amounts of recharge to the alluvial aquifer of Haouz.

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Session Classification :  Parallel

Track Classification :  Topic 5 - Tools, methods and models to study groundwater
Drinking water resources investigation in Papaïchton Village (French Guiana)

The village center of Papaïchton, located on the bank of the Maroni River in French Guiana, had about 3500 inhabitants in 2015, with a marked population growth. The demand for drinking water has increased by more than 5% over the last 5 years and the needs were estimated at 200m³/day in 2015. The supply was not sufficient, especially in the dry season where water cuts were necessary during the night. If demographic trends continue, drinking water requirements will reach 500m³/day in the next 15 years. Considering that the potabilisation of the Maroni River requires heavy and energy-intensive treatment processes, the supply of drinking water by groundwater remains the best option for this type of village isolated from the infrastructures of the coastal strip.

The geology of this sector is mainly composed of metavolcanic and tuffs rocks, intruded by quartz veins and a dolerite dyke. A combination of several prospecting methods were used to determine fracture zones and drilling targets. First, field investigations were conducted to clarify the existing geological map and to characterize the geomorphology of the site as well as the springs dynamics. Then, a vegetation lineaments study by stereoscopy, based on old and recent aerial photographs, was carried out. These lines frequently reflect corridor faults. Within the most interesting areas, a prospection by radon emanometry was conducted, with 202 gas samples in the ground subsurface. This method also gives clues on the location of the fractured zones. Finally, a geophysical prospection with eight electrical resistivity tomography, corresponding to 4345 linear meters enabled to highlight hydrogeological targets.

Following these investigations, four small-diameter exploration drill holes were carried out on more interesting hydrogeological targets in order to evaluate the potential at lower cost. Finally, two boreholes designed for the exploitation were drilled near the two most productive boreholes.

While most of the water wells from hard rock aquifer in French Guiana produce between 2 and 6 m³/h, the two operational boreholes can produce respectively 30m³/h (a record for French Guiana) and 5 m³/h. These results take into account the safety margins necessary for sustainable management of the resource, particularly in the event of a marked rainfall deficit.

This work demonstrates the importance of groundwater resources in the drinking water supply of isolated sites in French Guiana, in order to meet the demographic and development challenges of the territory.

In addition, the production results show how a combination of prospection methods enables to find interesting and productive hydrogeological targets in hard rock aquifers.

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Session Classification : Parallel

Track Classification : Topic 9 - Groundwater and socio-economic development in Latin-
America
The Project of Enhancing Groundwater Knowledge and Governance for Sustainable Groundwater Management was initiated by Department of Groundwater Resources (DGR), Ministry of Natural Resources and Environment in order to investigate and apply a concept of groundwater governance in five selected groundwater basins comprising of Lower Chaophraya basin, Chiang Mai-Lumpoon basin, Udonthani-Sakolnakhon basin, Hat Yai basin, and Rayong basin. In this project, each basin was studied under the collaboration among DGR and five Thai universities which were Chulalongkorn University, Chiang Mai University, Khon Kaen University, King Mongkut’s University of Technology Thonburi, and Prince of Songkla University. The main objectives of this study are (1) to investigate and analyze a suitable approach of groundwater management under a concept of groundwater governance in five groundwater basins; (2) to develop a groundwater network and its database and communication system; (3) to enhance and promote groundwater knowledges; and (4) to propose a strategic and action plan for developing groundwater network. In this research, both qualitative and quantitative methodologies were employed to discover and understand a complicated interaction among stakeholders involved in Thai groundwater management which are households, industries, farmers, local governments, central governments, groundwater drillers, and non-profit organizations. In terms of research method, this research utilized questionnaires and focus group meetings to obtain responses from groundwater users and related stakeholders and agencies in Thailand. Furthermore, in-depth and semi-structured interviews of key informants were included in order to examine real insider perceptions as it is meaningful properties of the social reality and find a better way to create a groundwater network and sustainable groundwater management. The results from the study demonstrate that most aforementioned stakeholders lacked groundwater knowledge, especially in terms of technical, management and legal issues as groundwater is invisible resources. More importantly, the process of groundwater management in each groundwater basin is not static, but dynamic, and is also highly complex, varying according to hydrogeological, socio-political and cultural contexts. Furthermore, this study suggests that in order to strengthen groundwater governance in Thailand, more adaptive and flexible management and participatory approach which is appropriate for each groundwater basin should be applied and studied in every basin and sub-basin. Therefore, enhancing groundwater network and knowledge dissemination is essential to support sustainable groundwater management under the governance perspective in Thailand.

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Session Classification: Parallel

Track Classification: Topic 3.1 - Groundwater and water security in developing countries
Multiscale impact of widespread managed aquifer recharge (MAR) implementation in the state of Gujarat, India

The state of Gujarat is located in an arid to semi-arid area in western India. Throughout history, the state has witnessed several famines and droughts. At the present time, the region continues to be subjected to water stress due to high inter and intra annual rainfall variability, further exacerbated by climate change and population growth. As a result, groundwater represents a vital resource for drinking, domestic and especially irrigation supply. In fact, it accounts for almost 80% of the total irrigation demand in the state.

Due to the rapid agricultural development over the last decades, the region has been subjected to groundwater overexploitation. In order to cope with the unsustainable use of groundwater, the government implemented new energy policies to rationalise abstractions and promoted decentralised water harvesting structures to recharge the aquifers.

Many studies have reported a significant rejuvenation of the water levels with a reversal in the declining trends of groundwater storage in the last decade. However, there is still a lack of scientific evidence regarding the cause of this rejuvenation. Multiple possible drivers have been proposed, including: the change in rainfall patterns, the introduction of new energy policies by the government, the import of surface water from the Sardar Sarovar dam and the widespread implementation of rainwater harvesting structures for MAR.

The aim of this study is therefore to thoroughly assess the impact of widespread MAR on groundwater resources. This was done by combining local and catchment scale assessments of MAR impacts through a multi-scale analysis. The study area chosen for this analysis is the Bhadar basin (6500 km²), located in the southwestern part of the Saurashtra peninsula in Gujarat. This area is characterised by hard rock aquifers and has witnessed the strongest development of MAR structure among the state, with more than 4000 check dams only in Bhadar basin. Because of the fore-mentioned discussion over Gujarat aquifers’ replenishment, and the scale and intensity of MAR implementation, this region offers a unique opportunity to assess the large-scale impact of this technique.

In this part of the study, the focus is on the local scale MAR structure impacts. This entails the systematic analysis of 3 representative MAR structures in terms of recharge capacity, availability of water recharged underground for its subsequent use, water balance of structures, and dynamics of water demand, in terms of irrigation practices, crop patterns and calendars. A MAR typology is then used to upscale to the basin scale applying local findings.

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Session Classification : Poster with refreshments
Track Classification:  Topic 1 - Groundwater assessment and management
Assessing recharge dynamics by the use of remote sensing and stable isotopes in the arid region of the Nubian Sandstone Aquifer System of Northern Chad

Monday, 23 September 2019 15:00 (15)

The Nubian Sandstone Aquifer System (NSAS) is a transboundary aquifer shared between Libya, Egypt, Sudan and Chad. The NSAS is one of the largest aquifers of the world. Groundwater is the only available water resource for most of the population living within its boundaries, given the extreme aridity that characterizes the region. The NSAS of Northern Chad might correspond to the least exploited and to the least investigated part of the system. The region is characterized by two mountainous regions, the Ennedi and Tibesti Mountains, experiencing increased precipitation rates (approx. 100 mmy⁻¹) compared to the mean regional rates (< 5 mmy⁻¹). Albeit small in quantity, recharge occurring in these mountainous regions might constitute an important, renewable resource. Previous authors studying the hydrodynamic properties of the NSAS have also concluded that modern recharge might play a role in maintaining higher hydraulic heads and gradients, thus slowing down the depletion of the NSAS. In view of a likely increase of exploitation of this aquifer in Chad, it is essential to characterize the temporal and spatial dynamics of modern recharge and to assess its influence to the regional aquifer system.

Key challenges of this project were the remoteness of the region and the lack of ground-based monitoring climatic and meteorological data. In the framework of the ResEau project, several fieldwork campaigns were undertaken between 2013 and 2016, covering approximately an area of 100,000 km². Hydraulic heads measurements, physico-chemical groundwater characterization and water probe sampling were performed for 185 water points. Water samples were analyzed for their major anions and cations concentrations and stable isotopic ratios (δ18O and δ2H). Remote sensing products (RFE2.0, LandSat8OLI) were employed to visualize the temporal and regional dynamics of precipitation, runoff and evapotranspiration and to quantify the system gains and losses. The period of observation was set between years 2013 and 2016.

The combined use of remote sensing products, fieldwork and the groundwater chemical and stable isotopic characterization enabled to qualitatively assess the relative importance of diffuse and concentrated recharge within the mountainous regions of Northern Chad. A groundwater flow conceptual model was developed in order to formulate hypothesis on the relationship between the zones experiencing modern recharge and the regional aquifer system. Groundwater’s hydro chemical and stable isotopic compositions shows distinctive characteristics whether if recharged during the current climatic period or corresponding to paleo-groundwater recharged during the previous humid but cooler periods of the late Pleistocene to Holocene. This distinction has important implication for water management.

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Session Classification : Parallel
Track Classification: Topic 1 - Groundwater assessment and management
Taking a deeper look - revisiting our understanding of deep (>200 m) groundwater systems

Recent interest in use of the deep subsurface for energy and storage has highlighted a lack of knowledge about groundwater at depths greater than about 200 m – the maximum usual depth for groundwater abstraction in the UK. Questions are being asked about the quality and availability and therefore future resource potential of deep groundwater, and its role in linking the deep subsurface and shallow groundwater resources. However, a lack of data and understanding of fluid properties in the deep subsurface, often resulting from difficulties accessing, measuring and/or retrieving information from such depths, means that deep groundwater systems are still relatively poorly understood.

Here we describe initial results from a project bringing together information from a range of sources to produce a UK-wide resource that can be used to improve the knowledge and understanding of the deeper subsurface including groundwater processes and environmental response. The initial phase of work has focussed on collating Total Dissolved Solids (TDS) data in order to understand the distribution of water quality with depth, and in particular the base of freshwater aquifers. Analysis of this data indicates that freshwater may be present to a depth of about 500 m, with brackish water present to a depth of about 1 km. An understanding of basin history, geology, past and present hydrogeological systems and past climates are key to understanding this distribution. Results from preliminary work on collation and analysis of UK-wide groundwater chemistry (TDS/Specific Electrical Conductivity, major, minor and trace ions and environmental tracers such as stable isotopes and noble gases), deep groundwater pressure/head and hydrogeological property distributions (e.g. permeability/hydraulic conductivity, porosity, storativity, transmissivity) is providing insights into regional deep groundwater flow systems.

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Session Classification : Poster with refreshments

Track Classification : Topic 1 - Groundwater assessment and management
The relationship between Groundwater Governance and Management at Local Municipal Level.

Tuesday, 24 September 2019 12:00 (15)

The terms ‘Management’ and ‘Governance’ are used interchangeably when referring to groundwater such as policy, protection, operations, financial systems and infrastructure. Governance and management are not separate scales of action, but different processes. Both processes can take place together at local, regional, national or global scales. (Seward 2015).

The influences from the different levels of government are also linked. Although governance is seen as more a national government function, some governance function can only be facilitated at a micro (local) level and not at the macro (national) level. This concept gave rise to the approach of national thinking but local implementation.

Governance and management can in most case not be split into two blocks and handled separately. To have sustainable groundwater resource delivery to a community both groundwater governance and groundwater management need to be in place. In most cases, the line between governance and management is seen as a straight line with a direct relation. In practice, this is rarely possible with governance or management functions always done at a fixed relation at different government levels.

The degree of governance vs management differs per level of government from institution to institution. The line between governance and management is thus very flexible between the different areas/location or aquifers where groundwater is being used and protected. The line can in one case be leaning more towards governance if more management functions are preform and vice versa.

The line between governance and management is not a thin line but rather a thick grey band. Some of the functions, responsibilities and roles are very difficult to place under governance or management alone and can fall under both. The same function can be seen by one organisation as a governance function because they see the function as a process and the other organisation see the function as a management function because it involves the implementation. The term ‘Implementation Governance’ was created to describe the overlap of functions, and this also links closely to the term ‘Local Level Governance’ that focuses on governance at the local municipal level.

At a national level more governance level functions, responsibilities and roles will take place than management and vice versa at the local municipality level it will lean more to management then governance. However, this also differs from municipality to municipality.

The paper describes the relationship between governance and management functions at different government levels and illustrates it through five scenarios/examples of the different government organisations at the municipal level.

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Session Classification : Parallel
**Track Classification**: Topic 3 - Groundwater sustainability and governance
A cross European project to understand the vulnerability of shallow groundwater resources to deep subsurface energy activities (VoGERA)

Monday, 23 September 2019 16:00 (60)

Society is increasingly looking to the subsurface for our energy needs, be that for extracting geothermal energy, shale gas, or buffering heat, gas, or storing by-products of energy production. An increasingly crowded subsurface presents risks to groundwater relied on for water supply, since subsurface activities can introduce or release contaminants and alter subsurface properties. The VoGERA project is investigating the vulnerability of shallow groundwater from a range of subsurface energy technologies across different hydrogeological and geological settings within Europe.

A suite of conceptual models compare the intrinsic vulnerability for different geological (crystalline, poorly consolidated and well consolidated sedimentary basins) and hydrogeological (basin centre and margins) conditions. They also consider the impacts of different subsurface activity types broadly categorised as those processes including injection, abstraction and a neutral fluid balance.

Potential contamination pathways are being investigated at four case study sites; the Rauw Fault in Belgium, Panonian Basin in Hungary, The Peel Boundary Fault in the Netherlands and the Vale of Pickering in the UK. Geophysical, hydrological and hydrochemical data from these sites will be assessed in order to improve contamination pathway process understanding in a European setting. Findings from the case study sites will be used to evaluate the conceptual models and to develop a tool for decision makers and the public to assess the vulnerability to shallow groundwater from sub-surface energy activities depending on the activity, and geological and hydrogeological conditions at a specific location.

The VoGERA project is funded as part of the European Union’s Horizon 2020 GeoERA network of projects under the Groundwater theme (Grant agreement number 731166).
A practical guide to conserving groundwater underground

Tuesday, 24 September 2019 15:00 (15)

Conservation is most likely linked to the behaviour of the user to use less water and to use the water more efficiently. The actions will include fixing the leaking taps, toilets and pipes; the implementation of best practices; and awareness programs. All these activities are after the water is taken from the water resource. However, the question remains: “Can water be conserved while still in the resource?” Moreover, then further “What is Groundwater Conservation?”

Conservation of groundwater is related to the use of groundwater at the right time and adopt a management style that suits the aquifer characteristics. By knowing when, where and how much to pump an aquifer can enhance the performance and life of an aquifer. By understanding the different operating rules levels and how the rules influence each other, the optimal yield can be determined. Climate variability and change is having a significant impact on our groundwater resource and the way we are managing our aquifers. Cost to pump and treat the groundwater can be cut with benefits not just to the municipality but also to the community and environment.

The paper will go into practical examples to understand the concept of groundwater conservation; to implement groundwater conservation at the local level and the benefits.

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Session Classification : Parallel

Track Classification : Topic 3 - Groundwater sustainability and governance
Making the unseen groundwater levels a drought indicator

Monday, 23 September 2019 16:00 (60)

South Africa is known for droughts and its effect on groundwater. Water levels drop, and some boreholes run dry during low recharge periods. However, how different groundwater levels indicate a drought?

The department monitors the water levels of just over 2000 geosites of which some monitored on a monthly, bi-monthly, quarterly and some bi-yearly base. The data is analysed from a national perspective to assess the groundwater level trends made. The analyses indicate the decline or rise in groundwater levels for the last ten years. The analysis was extended to provide a “Groundwater level Status” per each geosite. 2 boreholes with different geological settings, water levels, characters, etc. can be compared with each other for the first time. The current groundwater level is given as the status then the shallowest and deepest groundwater levels ever measured at the geosites are compared against the current groundwater level. The “Status” can now be used to indicate the severity of the drought and thus a possible groundwater restriction level indicator.

SDG Goal 6.6.1 on the change of the groundwater level calculation is base on the groundwater level status methodology.

The paper will present a detail methodology description and limitations of the methodology. The applicability to use the methodology from a national to a municipal level will be showcase through practical examples of the recent drought.

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Session Classification : Poster with refreshments

Track Classification : Topic 1 - Groundwater assessment and management
Empowering Local Drillers and Training Communities To Ensure Groundwater Resource Sustainability by Adequate Self Flowing Well Design and Drilling

The Rejoso Watershed, located in Pasuruan District, East Java, Indonesia, is facing the issue of the depletion of its groundwater resource at least since 2007. The cause is related to the high number of improper drilled self-flowing wells. These low-cost wells are funded by the local communities and are mostly used for agricultural needs (paddy field, annual crops and livestock).

These improperly drilled wells are not grouted, nor screened. As a consequence of no grouting, they lose lots of groundwater without any use, as (i) they leak through their annulus, and (ii) they flow year/day long, also when water is not used. In fact, their owner fears that valving them will reduce their productivity. This fear is partly grounded as annulus leaks may increase following valving. Moreover, due to the absence of a screen, well also collapse and their lifespan is reduced.

In this paper the methodology developed to implement and educate both drillers and community is presented on how to drill a proper artesian well called a "good water well" that can be controlled instead of making "bad wells" flowing about 5 litres/sec for 24/7, that have been spread around 600 units in the aquifer.

The methodology is 3 steps: (i) Drilling process, divided into drilling method, well construction, and grouting. During drilling, a hydrogeological log is elaborated from cuttings description and discharge measurements to locate the aquifer(s) and design the well. (ii) Wellhead construction design: the wellhead is equipped with an efficient valve to enable closing the well when water is not needed. (iii) Educating the local community, government, and private sector, through the implementation of the "Good water well", to the differences between "good" and "bad wells".

This initiative successfully completed a pilot good well flowing 7 litres/sec and closed the bad well nearby with grouting. The log showed that the shallow unconfined aquifer extends down to 60 m. The confined aquifer ranges from 60 to 65 m (bottom of the well). A blind 4" PVC pipe was installed in the 8" borehole (0–60 m) and the confined aquifer was screened. The annulus of the casing from 0–60 m was grouted and the artesian flow stopped in the annulus during the grouting process. To control the wells discharge and ensure monitoring, a flow meter, a gate valve, and a ball valve were installed. A transparent acrylic pipe was also installed to convince local water users that the water is not "disappearing" when the valve of the well is closed and that the well will not collapse, as the community believed. This good water well manages to save water and change the mind-set of the community, resulting in 150 ML/year saved groundwater.

Keywords: drilling, sustainability, artesian management
Session Classification: Parallel

Track Classification: Topic 3.1 - Groundwater and water security in developing countries
Inverse modelling of hydrogeochemical processes analysed along a flowpath within the Doñana National Park (Southern Spain)

Monday, 23 September 2019 16:00 (60)

The Santa Olalla pond is the only permanent pond located in the Doñana National Park (Southern Spain). Hydrochemistry of both surface and groundwater samples was analyzed during 2017 and 2018. Those samples were representative of the wet and dry seasons, respectively. In total, 22 samples were analyzed. Samples were taken in alignment with the general flow path from the dunes to the pond. Sampling points were: one medium-depth piezometer (21 m depth), three shallow piezometers (3 m) and surface water. Groundwater samples were taken using a pump and conserved for subsequent analysis. Physical-chemical parameters and iron analysis were measured in situ. Salinity values ranged from 45 mg/l at the beginning of the flow path, close to the dunes, to 8,850 mg/l in the pond itself. Facies varied from calcium-bicarbonate to sodium-chloride facies depending both on seasonality and location. The three inverse model scenarios performed with Phreeqc 3.0 and the database Wateq4f reveal sulfate reduction, redox reactions (Fe-S), mineral dissolution-precipitation, evaporation and mixing with deep water. These processes change seasonally, in accordance with hydrodynamic modifications in the flux directions in this pond. Minerals that were found to play a role in the pond hydrodynamics were calcite, gypsum, halite and pyrite. Evaporation was also found to be one of the main driving factors controlling the ionic composition in the surface water.

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Session Classification : Poster with refreshments

Track Classification : Topic 1 - Groundwater assessment and management
Stochastic simulation for characterizing the spatial variability of the groundwater level of an urban karstic aquifer in Brazil

Thursday, 26 September 2019 16:00 (60)

The study of the spatial and temporal variations of groundwater level (GL) is essential for allocation of groundwater resources and management of contaminant sites. Commonly, GL data is obtained in the field only in limited positions, at monitoring wells. Interpolation methods, herein referred to as deterministic geostatistics, are used to estimate groundwater level values at locations where it was not measured. Assessment of groundwater level at un-sampled locations is a common requirement during hydrogeological studies. Deterministic methods of geostatistics such as Kriging have been routinely used to interpolate random variables such as GL and to estimate their values at un-sampled locations. These methods result in smoothed fields of the groundwater level, that do not honor the spatial correlation function of the random variable, and ignore the uncertainty related to the lack of information in the un-sampled locations. In this work, a stochastic method is used to do coherent assignments of values at locations where measurements were not taken, based on the groundwater level observed at measurement locations. With the aim of characterizing the spatial variability of the groundwater level, it was measured in 50 monitoring wells located in an urban karstic aquifer in Brazil. Statistical and geostatistical analysis were conducted. The Stanford Geostatistical Modeling Software (SGeMS) was used to compute the experimental variogram from the 50 measurements. SGeMS was then used to fit a variogram model. Within the framework of the random field theory, GL is modeled as a random variable at each location in space, and 500 equally likely realizations (regionalized fields) were generated using the Sequential Gaussian Simulation (SGS) algorithm implemented in the code GCOSIM3D. In addition, we compare the results of SGS with those from Kriging. The characterization of the GL using SGS resulted in non-smoothed fields and allowed the quantification of the uncertainty. Throughout the analysis, it became clear that the use of deterministic methods of geostatistics for mapping the spatial variability of the groundwater level should be done with caution, especially when this information will base management of water resources and risk analysis.

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Session Classification : Poster with refreshments

Track Classification : Topic 7 - Karst Hydrogeology
Optimization of water resources in the rural environment: modelling tools for evaluating conjunctive use of ground- and surface-water and for crop yield estimate

Tuesday, 24 September 2019 12:00 (15)

Water Resource Management (WRM) is being getting attention, due to overexploitation and climate change affecting water quality and quantity. Conjunctive use of ground- and surface-water is increasingly being a common practice, especially in rural areas, for ensuring crop production sustainability. ICT (Information and Communication Technology) solutions, such as GIS-integrated simulation models, are suitable candidates to evaluate water resources optimization for reducing the impacts of agricultural practices.

WRM in rural environments represented a hot topic within the HORIZON 2020 FREEWAT project. The main result of the efforts spent for this purpose is an open source and public domain, QGIS-integrated modeling platform for the simulation of several processes involved in the hydrologic cycle (e.g., groundwater dynamics, interaction with surface water, solute transport, conjunctive use of ground- and surface-water).

Within the FREEWAT platform, conjunctive use of ground- and surface-water is accomplished by the Farm Process (FMP) embedded in MODFLOW-OWHM (MODFLOW One-Water Hydrologic Flow Model). FMP integrates the hydrological budget calculated by MODFLOW-2005 with supply-and-demand components of irrigated agriculture on a farm scale. Within the FREEWAT platform, FMP was coupled to the Crop Growth Module (CGM), a radiation-based model belonging to the EPIC family models, which simulates the crop growth cycle, and estimates crop yield at farm and basin scale, under different climatic and water supply constraints. The coupling between FMP and CGM is guaranteed by water availability in the unsaturated zone, and crop water demand and water uptake, as computed by FMP.

The FMP-CGM approach has been demonstrated through a synthetic application, where the growth cycle of irrigated sunflower in a Mediterranean area is simulated between 1st April and 31st August 2017. Model results show that the irrigation demand over the cropping season can be fully satisfied by natural uptake and surface water resources up to the end of May, while groundwater pumping is needed during the summer season, due to poor surface water availability and increased evapotranspiration demand. Supply-and-demand components of the irrigated area are quantified (e.g., rainfall recharge, irrigation by ground- and surface-water resources, root uptake, water percolation to the aquifer, evapotranspiration). Sunflower yield at harvest was also inferred according to weather and water availability conditions.

The proposed solution is thought to support the design of irrigation schemes for managing conjunctive use, thus reducing unplanned and unmanaged use of private irrigation wells. In this view, capacity building activities are needed to boost digitalization in the agricultural water sector for improving WRM.

Acknowledgements
This paper provides exploitation of the H2020 FREEWAT project (FREE and open source software tools for WAter resource management; www.freewat.eu) results. The FREEWAT project received funding from the European Union’s HORIZON 2020 research and innovation programme under Grant Agreement n. 642224.

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**Session Classification:** Parallel

**Track Classification:** Topic 3 - Groundwater sustainability and governance
Devise strategies and modelling tools to target the objectives of the EU Nitrates Directive and to enhance agricultural water management

Monday, 23 September 2019 16:00 (60)

During the last decades, severe qualitative and quantitative imbalance is being detected for many important aquifer systems worldwide, even beyond the limits of sustainability, due to overexploitation and climate change. Among the most challenging topic, the increase of nitrate concentration in groundwater, especially in rural areas, is a matter of concern. More than 20 years after the issue of the EU Nitrates Directive, the spatial/temporal trend of nitrates in groundwater is still poorly understood. As argued within EU water-related Directives, ICT (Information and Communication Technology) may provide proper tools (e.g., numerical models and GIS (Geographic Information Systems)) to address integrated water resource management.

Efforts have been spent in this direction within the framework of the HORIZON 2020 FREEWAT project, whose main result is a composite QGIS plugin, the FREEWAT platform, which couples the power of GIS geo-processing tools for spatial data analysis with that of free and open source process-based simulation models (e.g., MODFLOW and other codes developed by the USGS) for the simulation of the hydrological cycle. Taking step from FREEWAT results, the general objective of the SMAQua project (SMArt ICT tools per l’utilizzo efficiente dell’AcQua - smart ICT tools for efficient water use) is to deal with water quality issues by means of smart software applications aimed, among the others, at reducing the impact of irrigated agriculture.

In order to fulfill the objectives of the Nitrates Directive, a tool for the simulation of the nitrogen cycle in the unsaturated zone has been integrated within the FREEWAT platform. The integration strategy consists in coupling vertical flow through the unsaturated zone and surface runoff, as simulated by MODFLOW, and all the processes involved in the nitrogen cycle, as simulated by the ANIMO (Agricultural Nutrient Model) model. The latter is a lumped code which simulates nutrients leaching to the water table, taking into account agricultural strategies, soil properties, land use and the hydrological conditions. The coupling approach consists in downscaling at the grid cell scale, all the processes simulated by ANIMO at the basin scale. As a result of the coupling methodology, the amount of nitrate which reaches the water table by percolation is estimated and treated by solute transport models (e.g., MT3DMS) for the simulation of advection-dispersion processes in groundwater.

The proposed solution is thought to provide innovative and digital tools for companies and water authority to evaluate the impacts of agricultural practices on water quality and to enhance agricultural water management.

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The SMAQua project has been co-financed by Regione Toscana, ASA S.p.A. and ERM Italia S.p.A. This paper provides exploitation of the H2020 FREEWAT project results. The FREEWAT project received funding from the European Union’s HORIZON 2020 research and innovation programme under Grant Agreement n. 642224.
Track Classification: Topic 5.3 - Advanced modelling tools for subsurface hydrology: from the vadose zone to deep environments
Origin of Groundwater Salinity in the vicinity of Lake Fitri, Central Lake Chad Basin

Thursday, 26 September 2019 15:45 (15)

The Lake Chad Basin is characterized by variable climatic and physical conditions. Its southern part receives increased rainfall, mainly collected by the Chari-Logone Rivers, while the northern part is dominated by more arid conditions. Lake Fitri, in the Central Lake Chad Basin, is a miniature of Lake Chad at the western tip of the Batha River. Both lake and river water are available water resources, but populations are mainly dependent on groundwater for their daily needs. However, groundwater quality is often poor in this part of the basin. In this study, we focus on the Quaternary Aquifer north of Lake Fitri in order to characterize the groundwater types and to assess the origin of salinity measured through its Electrical Conductivity (EC). The study is conducted within the framework of the ResEau Project through its support to the GIS-Hydrogeology Program (Master HydroSIG) of the University of N’Djaména (Chad). A fieldwork, carried out in November 2017, resulted in the collection of groundwater samples and subsequent analysis of cationic and anionic contents, as well as δ2H and δ18O isotopic compositions.

This field-based investigation reveals the presence of a shallow aquifer, characterized by hydraulic heads above 280 masl, low EC values (average 1343 µScm-1) and a calcium-bicarbonate composition. At lower hydraulic heads (below 270 masl), groundwater is distinctively different, characterized by higher EC values (up to 20,600 µScm-1) and a sodium-sulfate composition. Strong correlations among SO4, Na and K, Na/Cl ratios of the analyzed samples and the occurrence of gypsum layers suggest that this chemical composition is mainly due to interaction of Ca-rich groundwater with K-Na sulfates, such as Hanksite (17Na2SO4.4Na2CO3.K2SO4.2NaCl). The isotopic compositions of the analyzed samples are in accordance with the hydrochemical patterns. Calcium-bicarbonate samples plot along a line δ2H = 5.84 x δ18O – 3.84 (R2 = 0.96) while sodium-sulfate samples plot along a line (δ2H = 5.58 x δ18O – 14.13; R2 = 0.96). The shift of the stable isotopic composition of the sodium-sulfate groundwater is in agreement with fractionation resulting from the interaction with evaporites characterized by heavy O isotopic compositions.

In addition to the identification of the origin of groundwater salinity in the Lake Fitri area, the characterization of the chemical and stable isotopic composition of groundwater is used to geographically locate sources of modern recharge. Such characterization is essential to develop an integrated water resource management plan for this region, particularly sensitive to climatic change. However, a more precise quantification of the resource is required to plan its sustainable use for agricultural, industrial and domestic purposes.

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Session Classification : Parallel
Track Classification : Topic 8 - Groundwater quality and pollution processes
The main geochemical characteristics of surficial and groundwater were studied in Jarales area (Cordoba Province, South Spain), an evaporite karst plateau characterized by the presence of endorheic wetlands and drained by brine springs. For four years, routine sampling of groundwater (springs and wells), wetland, and rainwater was carried out. The major ion composition of the samples was determined, and the saturation indexes of the main mineral species were computed, using PHREEQC code. The main elements affecting the hydrochemical composition of the considered points were identified performing a Principal Component Analysis (PCA), and inverse geochemical modeling was executed by means of the NETPATH software to investigate the geochemical evolution of groundwater along a theoretical flowpath.

The chemical results and their latter statistical treatment show a high inverse relationship between the elevation of the outlets and their water temperature and mineralization mean values, which is associated to a transition of the main hydrochemical facies: from Ca-HCO₃ to Na-Cl type, by way of Mg-SO₄ waters. The analysis of ionic relationships in groundwater evidences that the main processes explaining the geochemical transition of groundwater from recharge to discharge areas are halite and gypsum dissolution and, to a lesser extent, dedolomitization and dissolution of other evaporite minerals. Other minor reactions identified in the area are calcite precipitation (triggered by common-ion effect) and ion-exchange. The information derived from geochemical modeling, together with the mineral saturation state of the samples and their increasing rCl /SO₄²⁻ values, support the previous statements and suggests that the chemical composition of the NaCl-type groundwater is related not only with lithology but with their residence time within the media. All that combine suggests the existence of a large hierarchized gravity-driven groundwater flow system. Thus, the drainage taking place at higher altitudes (brackish water) may be associated with local flows of short residence time in the media. On the other hand, springs placed at lower positions would drain regional groundwater flows (brine water) of greater age. Lastly, outlets at intermediate positions do not constitute the last destination of groundwater flows, which rather go towards other areas situated at lower altitudes. The methods used in this research permits to better understanding the hydrogeological and hydrogeochemical processes occurring in the studied system, but also in equivalent evaporite environments worldwide.

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Session Classification : Poster with refreshments

Track Classification : Topic 5 - Tools, methods and models to study groundwater
Impact of rainfall structure and climate change on soil and groundwater salinization

Tuesday, 24 September 2019 12:30 (15)

Irrigated areas, mainly in arid regions, are threatened by salinization processes. Climate change inducing temperature rise and rainfall depletion is expected to enhance these processes. Numerical models are often used to estimate and predict water and solute fluxes reaching groundwater. Climatic data, mainly rainfall, have an important influence on the estimation of those fluxes. The present paper aims to study the impact of rainfall structure and climate change on soil and groundwater salinization. Soil samples were collected in three drip irrigated plots in Korba semi-arid coastal plain in Tunisia during dry and wet seasons. Collected field data (water contents and soil salinities) were used to define the initial solute and flow conditions and to estimate the soil hydraulic parameters for numerical modelling. Daily rainfall structure and annual rainfall transition under both Markov Chain and climate change (RCP4.5 and RCP8.5) were assessed. Different climatic scenarios were then introduced as boundary conditions in HYDRUS-1D, to test the influence of rainfall on solute fate. Results showed that both annual rainfall amounts and daily structure had an impact on soil concentrations and solute fluxes quantities reaching groundwater. Influence of rainfall paths was more important for higher unsaturated zone thickness when considering the dry and the median condition. Climate change scenarios showed significant accumulation of salts in the root zone implying the imperative use of adequate irrigation practices.

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Session Classification : Parallel

Track Classification : Topic 2 - Groundwater and climate change
Improving groundwater storage and quality in a seawater intruded multi-aquifer system by managed aquifer recharge

Thursday, 26 September 2019 09:00 (30)

Managed aquifer recharge (MAR) is being practiced for improving groundwater storage and quality. The objective of the present study is to access the impact of the check dams as a method of MAR on the spatial and temporal dynamics in groundwater quality. The present study was carried out in the Arani-Kortalalaiyar River basin, located north of Chennai, southern India where several check dams have been constructed. This area is also a part of the multi-layered coastal aquifer with an upper and a lower aquifer, which are affected by seawater intrusion since 1969. Due to the high rate of pumping from the lower aquifer for agriculture and public water supply, the extent of seawater intrusion is higher in the lower aquifer than the upper aquifer. Groundwater modelling carried out for the period until 2030 indicated that rejuvenating the unmaintained surface water bodies in the study area such as lakes, ponds etc., increasing the recharge through check dams and decreasing groundwater pumping will reduce the seawater intrusion from 14 km to about 8 km. Simulated results also indicated that with 10% increase in recharge and with 10% reduction from the current pumping rate, the groundwater levels will increase up to 3 m in the upper aquifer and up to 6 m in the lower aquifer. As an extreme scenario, the effect of 10% decrease in rainfall and 10% decrease in pumping was also predicted. This indicated that even though there is decrease in rainfall, by reducing the groundwater pumping, the groundwater levels will increase by about 1 m in both the upper and lower aquifers. The groundwater quality also improves as the chloride concentration decreases by about 1400 mg/l in the upper aquifer and about 950 mg/l in the lower aquifer at the end of 2030. Thus, check dams constructed along the non-perennial rivers help in reviving contaminated aquifers and improving the groundwater quantity and quality.
Developing a model for a transboundary aquifer in the water-scarce region of Central Asia

Monday, 23 September 2019 16:00 (60)

Due to climate change and increased human impact, water use and its protection have become one of the major regional issues in Central Asia. As the availability of surface water is decreasing and becoming erratic, the reliance and pressure on groundwater resources are constantly growing. That is also a case with the Pretashkent Transboundary Aquifer (PTBA), located between the Republic of Kazakhstan and Uzbekistan. Groundwater withdrawal from the aquifer is increasing, responding to the high demand for water supply and irrigation. Aquifer-sharing countries have started a dialog about water policy and management tools for the PTBA, including the development of an operational numerical model. This model is required for better understanding of the aquifer dynamics and for development of scenarios for utilization of this hardly renewable aquifer. The aim of this research is to develop a conceptual hydrogeological and a numerical model of the PTBA in a framework of transboundary cooperation.

The model is developed using the Groundwater Modeling System software (GMS). The model input preparation, including challenging transboundary harmonization (differences in language, classification, reference system, etc.) is conducted through a process of intensive discussion and collaboration among all international stakeholders. That was the main novelty of the conducted research. The conceptual model is the first major step in the development of the PTBA model and the first visible result of joint efforts to improve management of precious groundwater resources in the region. The following modelling steps are already stipulated by geological surveys of aquifer-shared countries and will be conducted with the continuous support of UNESCO-IHP and the Swiss Development Cooperation.

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Session Classification : Poster with refreshments

Track Classification : Topic 3 - Groundwater sustainability and governance
Theoretical analysis of well extraction and injection capacities under constraints on hydraulic head

Thursday, 26 September 2019 17:30 (15)

Subsurface wells are widely used for a number of applications including groundwater supply, managed aquifer recharge, oil recovery, and carbon sequestration that need extraction and/or injection of fluids. One of the primary requirements for successful and cost-effective well operation at a given site is that the hydrogeological conditions must allow for a sufficient well extraction or injection capacity. However, little discussion exists in the literature regarding how to estimate these capacities and what the dominant controlling factors are. We developed methods for estimating the capacity of single and multiple wells both in confined and unconfined aquifers under constraints on hydraulic head, and performed a parametric study to estimate the influences of the parameters (transmissivity, storativity, well operation duration and well radius) on the extraction and injection capacities. For a single well, the parametric study showed that transmissivity has the most influence on the well capacity while storativity has the least. For multiple wells, we analyzed the impact of well interference on the total capacity of the wells for different geometrical arrangements of the wells (linear, circular and grid arrangements) and as a function of well spacing. The results showed that well interference can imply a significant reduction of the total capacity. More precisely, the total capacity increases much less than proportionally with the number of wells, up to reaching an asymptotic value (i.e., beyond a certain number of wells, increasing the number of wells yields a negligible increase in the total capacity). The results also showed that a linear arrangement of the wells yields a larger total capacity than a circular or grid arrangement. The results of this study provide fundamental insights into well hydraulics under hydraulic head constraints and have practical implications on site selection and well field design.

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Session Classification : Parallel

Track Classification : Topic 5 - Tools, methods and models to study groundwater
Assessing the potential of denitrification through Managed Aquifer Recharge (MAR)

Monday, 23 September 2019 16:00 (60)

Nitrate (NO3) is a common contaminant in groundwater and surface water worldwide. Denitrification is a microbial respiratory process in which dissolved NO3 is reduced to nitrogen gas (N2). Research has shown that MAR can enhance natural attenuation of nitrates by accelerating denitrification that occurs during groundwater recharge and groundwater flow. However, very few MAR sites aim primarily at denitrification and the physical and biochemical processes controlling denitrification through MAR are not well-documented. This study aims at assessing the potential for denitrification through MAR, taking into consideration factors such as redox conditions, availability of organic matter, aquifer hydraulics and nitrate concentration. Based on a literature review, a conceptual model was developed which incorporates the most significant factors for enhanced biological denitrification. This conceptual model can provide the basis for a numerical model to obtain the optimal range of dissolved oxygen, redox potential and easily biodegradable organic matter which will lead to a maximum denitrification rate within a MAR setting. Using spatial distribution of soil parameters and other site characteristics, the potential for denitrification through MAR was mapped over Europe. This map can serve to select pilot areas for further experimental research in the field. Characterization of optimal conditions for denitrification through MAR and their spatial distribution can provide a focus for future field studies and ultimately assist practitioners and policy-makers to reduce nitrate contamination in aquifers.

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Session Classification : Poster with refreshments

Track Classification : Topic 5.3 - Advanced modelling tools for subsurface hydrology: from the vadose zone to deep environments
Endocrine Disruptors in groundwater of a Mediterranean Natural Reserve and Important Bird and Biodiversity Area (IBA) in Southern Spain: Fuente de Piedra basin (Málaga, Spain)

Thursday, 26 September 2019 17:00 (15)

The aim of this study was to detect and quantify the level of emerging contaminants in the groundwater of the Fuente de Piedra salt lake endorheic basin located in the Málaga province (Southern Spain). The Fuente de Piedra salt lake is an area of ecological importance due to its location, geology, hydrogeology and climate. For this reason, in 1983 it was declared as a RAMSAR site and in 1984 it was declared as a Natural Reserve. Later, in 1988 it was declared as an Important Bird and Biodiversity Area (IBA) and still is to this day. A sampling campaign was carried out to extract the groundwater samples from the study area. The sampling network consisted of 22 points distributed all over the basin. The emerging contaminants analysis was carried out in the Research Services of the Institute of Marine Research (INMAR) in University of Cádiz (Spain). To this end, Gas Chromatography-Mass Spectrometry (GC/MS) after stir bar sorptive extraction (SBSE) was used in order to determine the targeted compounds in the groundwater samples. Results confirm the presence of a wide range of targeted compounds. However, unusually high concentrations of endocrine disruptors such as 17-α-ethinylestradiol (9-670 ppt), 17-β-estradiol (27-712 ppt) and Nonylphenol (1-67 ppt) were found. To our knowledge, it is the first time that such high concentrations of these chemicals have been detected in groundwater. Additionally, the ecotoxicological risk of endocrine disruptors was estimated using their risk quotients. The findings suggest that there is a significant ecological risk for green algae species but not for Daphnia or fish. Nonetheless, biomagnification of these compounds in the food chain could be a concern for other species living at this environment. Further epidemiological and toxicity studies are needed.

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Session Classification : Parallel

Track Classification : Topic 8 - Groundwater quality and pollution processes
Well radius of influence and well radius of investigation: Review of concepts and estimation methods

Tuesday, 24 September 2019 16:00 (60)

Well radius of influence and well radius of investigation are fundamental concepts in well hydraulics and well testing. However, a large confusion surrounds these concepts. Well radius of influence is loosely defined as the distance from the well at which the hydraulic head change induced by pumping (or injection) is negligible. Well radius of investigation is a closely related but different concept. Well radius of investigation is loosely defined as the distance from the well at which the aquifer properties have a negligible influence on the hydraulic head change at the well. In either case, several interpretations are possible of what may be considered as being a negligible hydraulic head change. Accordingly, various formulae have previously been proposed to estimate well radius of influence and well radius of investigation. These formulae can yield significant differences in the calculated values. However, there is no guidance as to when to use one formula rather than another. In this contribution, we present a critical review of available formulae and derive new formulae to overcome limitations of available ones. The formulae are classified into three categories: (i) formulae that are based on an absolute criterion, (ii) formulae that are based on a relative criterion, and (iii) heuristic formulae. This classification alleviates the confusion that surrounds the concepts of well radius of influence and well radius of investigation, and it highlights that different formulae may be best suited for different purposes. As an outcome, we propose a practical guide for choosing a suitable formula for well radius of influence and well radius of investigation according to the context of use.

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Session Classification : Poster with refreshments

Track Classification : Topic 5 - Tools, methods and models to study groundwater
Interactions H2O-CO2-rock in a vadose CO2-rich karst research site (surroundings of the Nerja Cave, Málaga, Spain)

Thursday, 26 September 2019 16:00 (60)

This study is based on the results of experimental measurements conducted in a 30 m-deep borehole (S6) near the Nerja Cave (Malaga province, southern Spain). The Nerja Cave is an important and large tourist cave, visited by 480,000 people annually. The selected borehole is located in a research site (RS) consisting of 9 boreholes that cross karst openings and cavities of the vadose zone of the Las Alberquillas aquifer. The S6 borehole is unique in the RS because it presents a perched water level in its final meter. Previous studies have identified vadose CO2 gas contents up to 60,000 ppmv in the RS that favours the aggressiveness of the recharge water. An experience was carried out introducing just above the water level two open vessels with distilled water: one with water only and the other with pieces of rock of the carbonate Triassic formation in which the borehole is located. The aim of the experiment was to understand the interaction H2O-CO2-rock in a high CO2 vadose atmosphere by means of comparing the composition of the water from the perched level and from the two vessels. This study presents CO2 gas-content profiles within the borehole, as well as physical-chemical and isotopic (2H and 18O of H2O and 13CDIC) data during 2015 for CO2 data, and 2016 and 2017 of the water from the perched level (S6) and from the two vessels. Our measurements indicates that pH values of the perched water changes seasonally related to variations in the CO2-rich air. In the vessels, the results report on the incidence of processes such as the concentration of the rainfall by evapotranspiration as well as the effect of carbonates dissolution in the vadose zone with relatively high CO2 content.

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Session Classification : Poster with refreshments

Track Classification : Topic 7 - Karst Hydrogeology
Multiple salinization processes along groundwater flow paths in a coastal irrigated plain, Korba, Tunisia

Friday, 27 September 2019 09:40 (15)

Groundwater investigations were carried out along two transects (S1 and S2) perpendicular to the shoreline in Korba coastal aquifer in northern Tunisia from 2006 to 2013. They involved groundwater sampling (for Na, K, Ca, Mg, Cl and SO4), stable isotopes (for 2013 campaign), piezometric measurements and Electrical Resistivity Tomography imaging. The objective was to identify the potential origin of groundwater salinization (ie high TDS and NO3) and to study associated processes. Historical data, set up since 1962, were also collected and analysed to evaluate time and space evolution of the salinization spread. Ionic ratios (ie, Br/Cl, Na/Cl, Mg/Ca, HCO3/Cl, Ca/(SO4+HCO3) and SO4/Cl) and ionic deltas, conventional diagrams and geochemical modelling using PHREEQC were also used. Besides, multivariate statistics techniques, Principal Component Analysis (PCA) and Hierarchical Cluster Analysis (HCA) were performed. The nature of prevailing flow systems may also be proposed, as there are flows of different salinity that were detected at different depths. The piezometric survey confirmed the inversion of the groundwater flow in transect S1 where a piezometric depression of 5 m was observed at 4,000 m from the shoreline. PCA reveals that two main processes are contributing to groundwater mineralization and thus salinization: seawater intrusion and agricultural contamination mainly through N-fertilizers. The geochemical impacted area of seawater intrusion was estimated to 4,000 and 1,500 m respectively along transect S1 and transect S2. Inversely, agricultural contamination is rather acting in internal areas beginning at 2,000 m and 1,500 m from the shoreline for S1 and S2, respectively. This suggests that the vertical components of flow are to be given consideration in the evaluation of the response to abstraction as the inducement of irrigation return flow to production wells.

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Session Classification : Parallel

Track Classification : Topic 5.4 - Innovative approaches for understanding groundwater flow systems
Hydrochemistry and water-rock interaction in perched Cretaceous aquifers from the inverted relief in the Sierra de Segura (SE Spain)

Thursday, 26 September 2019 16:00 (60)

Inverted relief of the Sierra de Segura area (province of Jaén, SE Spain) is characterized by the presence of numerous carbonate aquifers associated with topographic elevations of the Upper Cretaceous, which appear folded forming synclines. This geological structure controls the perched hydrogeological aquifer geometry, appearing in topographic highs and drained by numerous low discharge springs located in the geologic contact with the Albian sandy-marly impermeable sequence, called Utrillas Formation. Some of the most representative aquifers are Navalperal, Yelmo, Navalespino, Calar de Cobos or Bucentaina. To carry out the characterization of these springs, a monitoring network (60 groundwater samples and 7 rock samples) has been designed. Major, minor and trace elements were determined in water samples. X-ray diffraction (XRD) and scanning electron microscopy (SEM) analyses were carried out in the selected rocks for determining mineralogical and petrographical characterization.

Major hydrochemical facies are calcium-magnesium bicarbonate and the predominant minerals are calcite, dolomite, potassium feldspar and quartz. Different hydrochemical diagrams show groups of springs based on altitude and the contents of marker ions would indicate hydrogeochemical evolution of the groundwater of the aquifers of the studied sector and their water-rock interaction. The chemical quality of these waters are according to the Spanish standard criteria established by the law, due to the scarce or no human pressure on the area and the nature of the aquifer materials. This sector could be considered an ideal location to define a prime location in a Mediterranean environment, where human influence on natural water resources is scarce.

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Session Classification : Poster with refreshments

Track Classification : Topic 7 - Karst Hydrogeology
What can modern farms learn from older one? A lesson from ancient wise hydrogeologists

Tuesday, 24 September 2019 12:30 (15)

The southern Levant is an arid area with precipitation that doesn’t exceed 150 mm per year. Despite the arid conditions, agriculture flourished throughout extensive areas of the Negev Highlands, southern Israel, for hundreds or even thousands of years. The ancient agriculture was based on runoff harvesting and reducing floodwater energy. Currently, water is constantly supplied through pipes, therefore, this ancient knowledge seems to be irrelevant. However, modern hydrogeological research indicates that the ancient methods of terraces construction can be useful for the present. Close observations show several benefits of the ancient techniques: increased soil moisture behind restored terraces, improved soil fertility due to accumulation of organic matter, reduced soil erosion and even soil accumulation by trapping flowing sediments. Most of the challenges that ancient farms faced are relevant for modern agriculture in drylands. Therefore, we can learn from the wisdom of ancient agricultural practices to contribute knowledge for sustainable modern agriculture applies in drylands.

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Session Classification : Parallel
Track Classification : Topic 3 - Groundwater sustainability and governance
Natural radioactivity of groundwater, the new challenge in drinking water quality: how can flow system approach help?

Tuesday, 24 September 2019 11:15 (15)

Uranium, radium and radon are usually found in groundwater, as moving groundwater interacts with its environment, it can mobilise, transport and accumulate these isotopes similarly to other chemical substances. As groundwater represents the main source of public drinking water supplies in many regions (EU 75%, Hungary 88%), presence of natural radioisotopes in groundwater may pose a hazard factor to the public. However, in accordance with Council Directive 96/29/EURATOM, the risk from ionising radiation must be kept as low as reasonably achievable. The Council Directive 2013/51/EURATOM, therefore, lays down requirements for the protection of the health of the general public with regard to radioactive substances in water intended for human consumption. This was implemented in Hungary in 2015. Thus, nation-wide overview of the radioactivity of drinking water in Hungary became available only recently, since waterworks and authorities are measuring and generating data only in the last three years. Based on the results 11% of the measured gross-alpha and 3% of gross-beta values are above the threshold values. This indicates that in areas where elevated gross values are found natural radionuclides may pose a health risk to the public.

In general, however, there is no apparent relationship between the type of rock constituting the water-bearing formation and the observed activity concentration levels of the radionuclides, since wide ranges of activity concentrations of the radioisotopes are observed within the same aquifer. The theory of regional groundwater flow, however, puts previous observations in a different context. In case of redox-sensitive parameters, such as the uranium or radium, understanding groundwater flow systems is especially important. Areas of different hydraulic regimes – recharge, throughflow and discharge – as well as different order flow systems – local, intermediate, regional – even within the same aquifer are characterized by different geochemical environment. Groundwater flow system evaluation thus contributes to the understanding of the measured radioactivity in drinking water by providing explanation of the origin and transport of radionuclides. Furthermore, it helps to successfully predict favourable conditions for elevated radionuclide content enabling efficient and successful decision-making, resource management and involvement. Presented case studies based on the combination of flow system evaluation and nuclide specific analyses support the applicability and significance of this approach.

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Session Classification: Parallel

Track Classification: Topic 1 - Groundwater assessment and management
Application of water isotopes and hydrogeochemistry for the determination of water sources in the intensive agriculture area of Guadalhorce detrital aquifers (South of Spain)

In the Guadalhorce river basin (South Spain) diverse water resources come together: rivers, aquifers and reservoirs. Sampling campaigns carried out in previous years show that both the chemical quality and the isotopic signal of water supply and irrigation water vary according to different factors of anthropogenic (existence of reservoirs with different water quality, irrigation channels and groundwater pumping) and natural origin (precipitation variability between dry, medium and wet years). This situation modifies the waters isotopic signal between surface and groundwater in different zones of the basin (upper and lower basin) and its mineralization. There is an isotopic enrichment in the water molecule (18O, 2H) and an increase in chloride concentration along the groundwater flow. Water isotope signatures reveal that the majority of groundwater samples seem to be affected by evaporation processes (samples in a 18O-2H graph are plotted over an evaporation line of slope 4-5). In a 18O/Cl- plot it is also detected an isotopic enrichment in the water molecule but in combination with chloride concentration along the flow line. The relationship between 18O/Cl- at the upper and lower part of the basin is different with the quantity of rainfall. While at the upper part there are no changes in chloride concentration or isotopic enrichment between wet, medium or dry years at the lower part, we find variations over dry or medium rainfall years, which are those that occurred in the study campaigns. It’s considered that a variety of processes coexist: the influence of the water stored in the reservoirs; the isotopic fractionation of water during pumping and irrigation return processes; and mixing processes with surface water of better quality.

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Session Classification: Parallel

Track Classification: Topic 8 - Groundwater quality and pollution processes
Are 253 samples better than 65 samples? Urban groundwater monitoring in developing countries – Lessons learnt in N’Djamena, Chad

Monday, 23 September 2019 17:45 (15)

In the frame of a technical cooperation project between the Lake Chad Basin Commission and the German Federal Institute for Geosciences and Natural Resources, four groundwater sampling campaigns were conducted in the Chadian capital N’Djamena in 2013, 2016, 2017, 2018. 253 samples were taken from 67 private bore wells equipped with handpumps and 16 large-capacity production wells of the public water supplier. The first campaign was designed to get an overview of the chemical and bacteriological groundwater quality and included samples from 52 private wells from across the entire city area and 13 production wells within the city. The subsequent sampling campaigns were conducted for monitoring purposes. Many 2013 sampling points were broken or inaccessible in the following campaigns and were replaced by wells in the vicinity. Only 32 private and nine production wells were sampled in all four campaigns.

The 2013 campaign identified bacteriological contamination, elevated nitrogen, and fluoride concentrations as the main areas of concern. While 40% of the private and 23% of the production wells contained fecal bacteria, nitrogen species and fluoride were found (with one exception) to be below the WHO guideline values. Although the subsequent sampling campaigns confirmed this general picture, the overall benefit of the additional 188 samples was limited to the finding that nitrogen concentrations were increasing in some points. In 2016, 2017, 2018 two, five, and four samples, respectively exceeded the WHO guideline value of 50 mg NO3/L. However, the distribution of the nitrate hot spots were somewhat random and it was not possible to draw more than general recommendations (e.g. protection zones around wells) from these findings.

In 2019, a survey was started to measure the total depths of all sampled wells and to make an inventory of possible sources of contamination. Re-evaluating the collected data in the light of this additional information leads to some insights on contaminant pathways, but most importantly, clearly shows that the monitoring network needs to be optimized. (1) Before choosing a sampling location, the well depth must be known and the future accessibility ensured: Replacing a broken well by any random well in the proximity does not help, unless both wells are filtered in the same depth and additional sources of pollution can be out ruled. (2) The construction of new observation wells is inevitable, as our data proves that random wells close to production wells cannot be used for monitoring purposes. (3) An additional focus on mapping of the sewerage system (design and construction years) is necessary to make predictions about the future development of nitrogen concentrations. In technical cooperation projects, baseline samplings are an important tool to identify problems, but groundwater monitoring needs more careful planning to be cost effective.

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Session Classification: Parallel
Track Classification: Topic 5.3 - Advanced modelling tools for subsurface hydrology: from the vadose zone to deep environments
Groundwater is a very common drinking water source. In Hungary, 88% of the water supply is sourced from groundwater. Radioactivity of groundwater, as a possible threat and its hydrogeological background, had not been widely investigated until recently. Following the Euratom Drinking Water Directive the radioactivity of drinking water is screened in Hungary in the last three years by gross alpha and gross beta activity measurements. Whenever the measured concentrations surpass the limit values the long-term consumption of the water can lead to health issues. Based on data provided by the National Public Health Institute high values of gross alpha activity can be found in the southern foreland of Lake Velence. Previous studies already showed high uranium concentration values (compared to average crust values) related to the Velence Granite Formation in Velence Hills and to the carbonatic and organic-rich beds of the Ujfalu Formation in the southern foreland of Lake Velence. Until recently no observations and measurements were made regarding the radioactivity of the groundwater. Therefore, uranium, radium and radon concentration measurements were carried out in the adjacent area and interpreted in flow system context. A total of 53 samples were taken from surface water (springs and lakes) as well as from groundwater. Alpha spectrometry applied on Nucfilm discs was used to measure the uranium (234U+238U) and radium (226Ra) activity while radon (222Rn) activity was determined by TriCarb 1000 TR liquid scintillation detection. Pressure-elevation profiles, hydraulic cross sections, tomographic potential maps and potential difference maps were compiled to understand the groundwater flow directions and regime characteristics in the wider area. The areal distribution of the activity concentration values was interpreted regarding the groundwater flow system, physicochemical parameters measured onsite and in the laboratory. Those areas can be delineated where according to the flow conditions and the related geochemical environment the mobility of the uranium or radium and thus elevated activity concentration can be expected in groundwater. This novel approach may facilitate safe water management of drinking water supply systems.

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Session Classification: Poster with refreshments

Track Classification: Topic 5.3 - Advanced modelling tools for subsurface hydrology: from the vadose zone to deep environments
Hydroelectric use of the water supply system to the city of Oviedo (NW Spain)

Monday, 23 September 2019 16:00 (60)

The demand for drinking water of the city of Oviedo is satisfied in normal conditions with the contribution of the springs of the Aramo Mountains (Namurian limestones), whose surplus is regulated in the Los Alfilorios Reservoir, and water from the Asturian Consortium for water supply and sanitation (CADASA), coming from another council (Sobrescobio). In times of shortage (summer months) it is necessary to pump water from the Quaternary connected to the Nalón River (the main river in the region) between the reservoir and the city. The annual flow needed to supply Oviedo (220,000 inhabitants) distributes approximately in: 63% from the Aramo springs, 17% from the Alfilorios reservoir, 5% from the Nalón River and the rest is bought from CADASA. With the exception of the latter, the remaining waters are treated in the Cabornio Drinking Water Treatment Station (DWTS), located near the reservoir, before being supplied to Oviedo. This work presents the possibility of installing a multiple system of renewable hydroelectric use: i) between the Aramo springs and the Cabornio DWTS; ii) between this DWTS and the supply tanks of Oviedo, in both cases taking advantage of the difference in elevation, by means of turbogenerators; iii) between the Los Alfilorios reservoir and the Nalón River, by means of a pumped-storage hydroelectricity system which turbines during periods of high electrical demand (using turbogenerators) and pumps in off-peak hours. This design would allow to increase the flow extracted from the river when necessary, reducing dependence on external water. The proposed systems are economically viable and interesting from the financial point of view, obtaining positive values of VAN, IRR between 7 and 20% and amortization periods between 5 and 12 years. This resource could be used for sale or self-consumption, and its use should be enhanced, especially in an energy-dependent country. Additionally, the use of renewable energies has environmental advantages, such as saving CO2 emissions. These systems are framed within the concept of “sustainable city”, and can be extrapolated to the water supply hydraulic infrastructures operating in other cities.

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Session Classification: Poster with refreshments

Track Classification: Topic 1 - Groundwater assessment and management
Integrated hydrological models (IHM), have become nowadays a standard method in hydrogeology. The advantages of IHMs will be discussed based on their comparison with standalone groundwater models, the two models set up and calibrated within exactly the same study area (Lubczynski and Gurwin 2005; Hassan et al. 2014). Among the differences between the two modelling methods, the main is that in the standalone groundwater models, the driving forces are represented by recharge and groundwater evapotranspiration which are typically uncertain or unavailable due to the lack of data, while in the IHMs, by rainfall and potential evapotranspiration, which are much easier to acquire in the field and besides, they can be derived by remote sensing (RS).

A constant increase of IHM’s popularity and easy access to readily-available RS-products (freely available, web-based, RS data), created an avenue for enhancement of RS-applications in hydrogeology. Besides, with rapid earth observation technology development, also the quality and versatility of RS products continuously increases, providing data at successively improved spatial and temporal resolutions. Three IHM studies with RS applications in three different areas will be discussed: 1) Sardon Catchment (Spain) based on: a) Hydrogeophysics and remote sensing for the design of hydrogeological conceptual models (Journal of Applied Geophysics, 2014(110)); and b) Surface - groundwater interactions in hard rocks: an integrated modeling approach (Journal of Hydrology, 2014(517)); 2) Lake Turawa (Poland) based on Interactions of artificial lakes with groundwater applying an integrated MODFLOW solution (Hydrogeology Journal, 2018(26)); 3) Central Kalahari Basin (Botswana and Namibia) based on: a) Hydrogeological conceptual model of large and complex sedimentary aquifer systems (Physics and Chemistry of the Earth, 2018, doi.org/10.1016/j.pce.2018.05.006); b) Use of remote sensing and long-term in-situ time-series data in an integrated hydrological model of the Central Kalahari Basin, Southern Africa (Hydrogeology Journal, 2019, doi.org/10.1007/s10040-019-01954-9).

The review of the 3 study cases will be followed by a discussion on state of art (including limitations) of RS applications in IHMs and finally concluded with a vision for future developments in that field.

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Session Classification : Parallel

Track Classification : Topic 5 - Tools, methods and models to study groundwater
COASTAL FLOODINGS AND ITS CONNECTION WITH MOTRIL-SALOBREÑA AQUIFER (SOUTHERN SPAIN)

Monday, 23 September 2019 15:15 (15)

Southern Mediterranean has been considered one of the most vulnerable coastal areas in the world due to flooding episodes, especially in low-lying coastal plains and deltaic areas (Nicholls et al., 1999). During de recent decades, coastal areas are experiencing rapid socio-economic development and hence a population increase. Infrastructures and social activities can be particularly affected. Groundwater inundation is poorly recognized and frequently confused with surface water floodings (Hughes et al., 2011). Rotzoll & Fletcher (2013) highlighted the importance of having a detailed understanding of groundwater level spatial distribution and the processes that control changes in water-table height throughout the coastal zone. This research evaluates the response of Motril-Salobreña aquifer to flooding on the deltaic plain of the Guadalfeo river. Periodic floods occur on this area and it causes ecological damage to a wetland nature reserve “La Charca de Suárez” and economic damages to: buildings, crops, and industry and tourism sector.

From February 2018 to April 2019, continuous water table data had been compared with precipitation, sea level, wind direction and sea wave height records. During the measurements period, several flood episodes took place and they could be related with water level rises registered in the piezometers.

Our results showed that water table lift plays an important role in the permanence of these floodings. A higher water table reduces the unsaturated zone and hinder surface infiltration, increasing overland runoff. The high water table events can be generated by: i) the lowering of atmospheric pressure that rises sea level. ii) Precipitation. The thin unsaturated zone favours the fast rising of the water table after rain events. iii) Wind speed and direction. East and southwest winds produce large waves which drive seawater inland and producing a local rise of sea level. Therefore, different types of inundation can be detected on the basis of the dominant factor with variable effect depending on the area.

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Session Classification : Parallel

Track Classification : Topic 1 - Groundwater assessment and management
Using natural tracers and high frequency physicochemical monitoring as complementary tools to a groundwater flow modelling

Thursday, 26 September 2019 12:00 (15)

The island of Barthelasse is the largest river island in Europe. Groundwater from this island provides water supply for 180000 inhabitant consumption through the use of two pumping wells systems on the Barthelasse part and on the nearby Motte part of the island. Backwaters few hundred meter-wide separate the two parts of the island. Because of proximity of the river and backwater, the aquifer is highly vulnerable to river pollution. To evaluate this risk, a study has been done on the dynamic of water exchange between river, backwater and groundwater in a context of increasing water demands. A large set of sensors was deployed in the two pumping fields and the Rhône river, to do a high frequency monitoring of the physicochemical parameters, temperature, electrical conductivity and groundwater levels. Several sampling campaigns have been conducted each 15 days since January 2018, to measure $\delta^{18}O$, $\delta^{2}H$ and $^3H$. A pumping test of 1000 m$^3$.h$^{-1}$ during 24 h was conducted on 2 wells (P7 and P8) in November 2018 in the Motte pumping field. An isotopic and physicochemical monitoring was performed, including time lapse isotopic monitoring of $\delta^{18}O$, $\delta^{2}H$ and Rn in an observation piezometer (PRD3) located 35 meters away from the pumping wells, 60 meters from the backwater and 300 meters from the Rhône river. In addition, discrete samples were collected in several observation piezometers, in the pumping wells, in backwater and in Rhône river to analyse major ions, $^{13}C$ and $^3H$. The results enabled us to build a conceptual model of the hydrogeological system and suggest that the pumped water resulted from two mixing end members whose contributions changed according to the seasons. Three different behaviours were observed between P7, P8 and PRD3 involving a complex distribution of flow paths and time transfer. Even if the backwater and the river are close to the wells and observation piezometer, the results didn’t show any direct contribution of surface waters to the groundwater during the pumping test. Conversely, the pumping field in the Barthelasse part of the island proves to be strongly influenced by the backwater and river with a transfer time of few weeks. This will therefore make it possible to improve the current groundwater flow model, particularly regarding boundary conditions and the heterogeneity of parameters. An in-depth study is under development to elucidate the water transfers between groundwater of different origins and surface water systems in the island of Barthelasse in order to compare with the modelling results.

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Session Classification : Parallel
Track Classification:  Topic 5 - Tools, methods and models to study groundwater
Origin and distribution of saline groundwater at Ghis-Nekor aquifer, Al Hoceima, Central Rif, Morocco

Thursday, 26 September 2019 16:00 (60)

The Ghis-Nekor basin is located in Morocco at the northern mouth of the North Rifian Corridor. It belongs to the post-nappe Neogene basins formed after the main orogenic movements of the Rif. Recent sediments Miocene and younger deposits overlying the previous units are encountered in the triangular Ghis-Nekor basin. A geochemical tracer and isotopes δ²H, δ¹⁸OH₂O, δ³⁴S, δ¹⁸OSO₄ was used to explain the processes responsible for the salinization of groundwater, and for identifying areas most vulnerable to seawater intrusion. The majority of sampled wells indicate high values of electric conductivity and total salinity which arrives at 7.5 g L⁻¹, with sodium chloride-facies and chlorinated calcium and magnesium sulfated facies. The concentrations of ¹⁸O range between −4.15‰ and −5.73‰, while the values of ²H range between −28.4‰ and −41.7‰. The Nekor river water is depleted in heavy isotopes, and the isotopic compositions are in the order on −6‰ for ¹⁸O and −40.5‰ for deuterium. The isotopic concentrations of ¹⁸O-SO₄ vary between 4.35‰ and 8.60‰, while the ³⁴S isotope values range from −4.3‰ to 9.9‰, all samples have the same isotopic signal as Miocene Marls. For Ghis River, these values are between −4.4‰ and 4.95‰, respectively, for sulfur and oxygen. The interpretation of the chemical and isotopic data suggesting the dissolution of NaCl and CaSO₄ containing in the Miocene Marls and sea water intrusion in the NE of the plain.

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Session Classification : Poster with refreshments

Track Classification : Topic 8 - Groundwater quality and pollution processes
Detection of groundwater discharge using handheld thermal imaging camera and orthophoto map analysis

Tuesday, 24 September 2019 16:00 (60)

Complex spring system was studied in Western Latvia using thermal imaging and orthophoto map. The study area is a protected geological monument containing group of springs with discharge 2-90 L/s. Freshwater limestone deposits are found there in the area of about 17 ha. The limestone was mined in 1930-ties and 1950-60-ties, but later abandoned pits were used for fish farming.

The aim of the study was to identify spring discharge and groundwater seepage locations in order to plan management of the area.

Handheld camera Flir E4 was used for thermal images. Drone DJI Phantom4 Professional with 2,54 cm 20MP camera sensor was used for aerial photography, from which orthophoto map was produced. Water temperature and conductivity were measured using WTW MultiLine P4 multimeter with TetraCon 325 electrode.

The study performed depends on season and air and water temperature. The field study was carried out in winter 2017-2018, when difference between air and groundwater temperature was at least 5 ℃ and there was no foliage or thick snow cover either.

The seepage of groundwater could be easily recognised on thermal images and their intensity depended on intensity of thermal signal. Thermal mapping of springs is challenging in underwater groundwater discharge places, where surface water temperature masks springs. The ratio of pond size and the spring discharge intensity matters in this case. The simultaneous water temperature measurements showed that in case of groundwater seepage and intensive spring discharge the thermal camera temperature measurements and manual measurements were close, within 0.5 ℃ range, but in case of underwater discharge the difference could reach 1-2 ℃. Therefore, thermal camera measurements cannot replace manual temperature measurements when precise data is needed, however, thermal mapping helps to pinpoint places where direct measurements should be conducted.

The season represented in orthophoto with captured floral characteristics of current spring ecosystem expressed as active plant growth near springs gives the color signature suitable for image classification and automatic delineation of these zones. Two approaches were tested and compared - unsupervised image classification and supervised classification using manually classified training polygons. Both approaches helped identify groundwater discharge locations, and worked well in underwater discharge cases as well.

This study showed that use of handheld thermal imaging camera provides good results in terms of identification of groundwater seepage zones and is rather effective in case of underwater springs. Combining thermal images with orthophoto analysis helps pinpoint places for detailed investigations in poorly accessible area.

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Session Classification: Poster with refreshments

Track Classification: Topic 5 - Tools, methods and models to study groundwater
Validation of vulnerability assessment by means of the Time Dependent Model: case study from the Slovenian karst catchment

Thursday, 26 September 2019 17:45 (15)

Groundwater vulnerability assessment methods are continuously being developed and existing methods are very often modified to provide better simulation of natural protection conditions and more objective results. Most frequently used methods are based on calculation of predefined parameters influencing water infiltration and underground flow, which can often lead to bias conclusions related to vulnerability evaluations. Some other methods, like the Time Dependent Model (TDM) are based on an approach, where parametrization is obtained at the final stage of the assessment. The main specifics are focused on the calculations of different flow travel time components, e.g., surface and groundwater flow (vertical flow path through the unsaturated zone, as well as horizontal flow path through the saturated zone). Moreover, the qualitatively different approach of vulnerability assessment enables direct translation of the results into sanitary protection zones according to the particular state legislation requirements. The TDM has been developed and successfully applied at several locations in the Serbian part of the Carpato-Balcanides. This paper presents its first application to the Slovenian part of the Dinaric karst and comparison to the most frequently applied methods of intrinsic vulnerability mapping in karst aquifers. An attempt to use the TDM as a groundwater assessment validation has also been made. The catchment of the Podstenjšek springs located at the Upper Pivka Valley in Southwestern Slovenia has been selected as a test site. In the past, four different methods of vulnerability mapping have already been applied (EPIK, PI, Slovene Approach, Simplified Method) to this test site using the same database and validated by means of tracer tests. The test site is characterized by temporal hydrologic variability, expressed by surface-groundwater interactions and variable drainage divides. The application of the TDM showed an alternative possibility to consider hydrologic variability in assessing groundwater vulnerability. In the case study it allowed clearer allocation of zones that are particularly vulnerable in various hydrologic conditions. The resulting groundwater vulnerability map shows the degrees of vulnerability, which are in direct function of surface and groundwater travel times and can thus be directly translated into protection zones according to Slovene legislation criterion. The results of the TDM assessment and comparison analysis can also be used as a tool for validation of vulnerability indices defined by other assessment methods.

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Session Classification : Parallel
Track Classification: Topic 7 - Karst Hydrogeology
Changes of the isotopic signatures and hydrochemistry in the unsaturated zone detected by a precision lysimeter installed in a dune belt (Doñana National Park, southwest Spain)

Friday, 27 September 2019 11:45 (15)

In September 2015, a high precision weighing meteolisimeter of 1.5 m height and a surface of 1 m² with lower boundary control was installed in the coastal dune belt of the Doñana National Park, southwest Spain. The infiltrated rainwater in the lysimeter has been drained into a drainage vessel. Both the lysimeter and the vessel weight have been recorded every minute. This study presents hydrogeochemical and isotope data of rain and drained water of the lysimeter to investigate water-rock-interaction in the unsaturated zone and to evaluate the possible effects of evaporation and condensation as well as mixing processes and residence times of the drainage water. Between October 2015 and June 2018 the content of 2H and 18O was analyzed in 49 water samples (21 rain and 28 drainage water). Additionally, between May 2017 and April 2018, hydrochemical analyzes of major components were also carried out in 10 rainwater samples and 8 samples of the drainage vessel. The results show a high variability of the rainwater composition ranging from Ca-Mg-HCO₃ to NaCl-type. The water in the drainage vessel ranges between NaCl and CaSO₄ types. Based on the isotope data, a local meteoric line (LMWL) has been derived. The LMWL presents a lower slope than the Global Meteoric Water Line (GMWL), while the lysimeter water line (drained water) plots below the LMWL, with less data variability than rainwater. The different position of the lysimeter waterline points to (i) additional fractionation processes of percolating rainwater in the unsaturated zone or (ii) a second water source different from rainwater related to condensation of vapor with a more humid origin than rainwater. The importance of vapor adsorption was already detected by the evolution of the Lysimeter weights yielding daily amounts between 0.3 and 0.5 mm in periods without rain. Future work will consist in analyzing the isotopic content of 2H and 18O of the atmospheric vapor, condensed vapor and pore water of the unsaturated zone in the vicinity of the lysimeter to quantify the possible contribution of this component.

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Session Classification : Parallel

Track Classification : Topic 5 - Tools, methods and models to study groundwater
Dating groundwater with radio-krypton and radio-argon

Thursday, 26 September 2019 12:30 (15)

The long-lived noble-gas isotope $^{81}$Kr, $^{85}$Kr, and $^{39}$Ar are ideal tracers for environmental samples, and can be analyzed using the Atom Trap Trace Analysis (ATTA) method [1]. $^{85}$Kr dating covers the age range of 2 – 50 years; $^{39}$Ar covers 50 – 1,400 years; $^{81}$Kr covers 40,000 – 1,300,000 years. In order to meet the increasing demands from the earth science community, we have established a new laboratory dedicated to radio-krypton and radio-argon dating. For Kr-dating, the required samples is 1-2 micro-liter STP of Kr gas, which can be extracted from 10-20 kg of water or ice; for 39Ar-dating, the sample size is 1-2 mL STP of argon, corresponding to a few kg of water or ice. We perform dating not only on groundwater but also on glacier ice and seawater. Here, we present both the latest technical development and earth science applications, including ATTA systems, degassing devices for groundwater, purification systems for dual krypton/argon output as well as examples of groundwater studies.

http://atta.ustc.edu.cn/en-us/events/attaprimer.html or Google "ATTA primer"
Assessment of groundwater natural recharge in difficult environments: A case study at the Lake Chad Basin

Monday, 23 September 2019 16:00 (60)

Reliable recharge assessment for sound hydrogeological analysis in arid and semi-arid area is a challenge due to the complex process requiring of intensive data mining and especially in face of limited access to data sets or only short data periods available. This has forced researchers to improve the available data using remote sensing products for input data (e.g., TRMM, CMORPH, TMPA). Recharge estimation through a water-soil-plant distributed model based on satellite products appears to be an interesting solution being adopted at the Lake Chad Basin for the Maiduguri area (Southwest of Lake Chad basin). Natural recharge is performed with a water-soil-plant distributed model (Visual Balan) based in meteorological data obtained from a ground station (Maiduguri, 532 mm) and from satellite products (MSWEP, 673 mm) for the same geographic location of ground station and satellite for the 2009-2010 period. Satellite products generally overestimate precipitation with regard to ground station; this fact is attributed to no raining cirrus with cold cloud-top temperatures. As a result, groundwater recharge estimation in the area by field stations and satellite products is 80 and 100 mm per year respectively, a 20% of difference in the final value. Considering the non-linearity of aquifer recharge process and dependence on precipitation values, comparison between ground-based and satellite data sets is the initial step for recharge estimation assessment.

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Session Classification : Poster with refreshments

Track Classification : Topic 1 - Groundwater assessment and management
Comparative analysis of geophysical techniques to characterize shallow groundwater conditions

Thursday, 26 September 2019 17:00 (15)

Measuring depth to groundwater is one of the most fundamental and basic observations in hydrogeology. Traditionally, this is done in piezometers or boreholes. Using interpolation (and extrapolation) techniques the point measurements are generally used to create a water table surface, which can result in significant error due to sparse measurements and also subtle changes in the low lying topography. In semi-arid regions assessing zones with shallow groundwater depths is crucial, especially when agricultural development could result in rising water tables. However, limited availability of and/or high costs of installing piezometers means that we still lack methods of fast and reliable estimation of depth to groundwater. An obvious interesting opportunity is to use non-intrusive hydrogeophysical sensing techniques.

The arid plains north of Adelaide, South Australia (~450 mm/yr rainfall) are an important food growing area. Recent proposals to extend the irrigation area (sourced from treated sewage plant effluent) needs to be evaluated closely, as groundwater quality and depth to groundwater are variable and not well known. High risk areas are zones where the groundwater is shallower than 3 to 4 m. In these areas even slight over-irrigation will result in rising groundwater tables and soil salinisation.

We have collected geophysical data sets at three study sites within the Northern Adelaide Plains (NAP), South Australia. Techniques evaluated include: a frequency domain, shallow terrain conductivity meter (CMD); a fast-sampling time domain electromagnetics system (TEM); a resistivity system (ERT); and a shallow reflection seismic system where first arrival times and surface waves were processed together to estimate depth to groundwater. Additionally, to provide further information on soil variability, as well as groundwater depth and quality, 47 geoprobe boreholes were drilled to 6 to 8 m depth. If water was encountered these holes were extended and logged using a shallow borehole nuclear magnetic resonance (NMR) system.

Comparison of the techniques and evaluation of the results suggest that: a) while much of the study area is flat, subtle features in the landscape (predominantly ephemeral streams) appear to be important conduits to supply water to shallow and perched water tables; b) the seismic survey appeared to provide useful information about depth to groundwater; c) Geophysical techniques that measure the ground conductivity (i.e. the electrically- and electromagnetically-based techniques TEM, ERT, CMD) can determine the depth to groundwater when there is a sufficient contrast between the conductivity of the groundwater and the background soils; d) In-situ results of water content and water boundness (soil texture) obtained using the NMR downhole tool were generally consistent with those obtained from samples collected and evaluated in the laboratory; and e) Borehole NMR has the potential to identify the presence of heavy clays that could impede infiltration.

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**Session Classification**: Parallel

**Track Classification**: Topic 5 - Tools, methods and models to study groundwater
Groundwater connectivity of a sheared gneiss aquifer system in the Cauvery river basin (peninsular India): Implications for water resources

Tuesday, 24 September 2019 15:00 (15)

The Berambadi (Kabini Critical Zone Observatory) is an 84 km² sub-catchment of the Cauvery river basin in the west of Karnataka, India. Intensive crop irrigation in the catchment is highly dependent on the supply of groundwater from a dense network of boreholes penetrating the peninsular gneiss aquifer. Large inter-annual variations in groundwater levels are observed in the catchment, where a single, heavy monsoon can compensate for several years of groundwater level decline. Extensive specific capacity data and groundwater level monitoring form the basis of a numerical transect model, which is used to explore the functioning of the fractured aquifer. The model results are compared with hydrogeological investigations, including inorganic hydrochemical analyses, δ18O and δ2H stable isotopes, CFC-11 and 12 and SF6 age-tracers, and salt dilution tests.

Numerical modelling indicates that lateral groundwater flow comprises only a small part of the water balance and water availability is controlled by local recharge and abstraction. Limited lateral flow is thought to be the result of shallow hydraulic gradients caused by widespread high abstraction, rather than poor connectivity in the fractured gneiss. This is supported by geological observations, which indicate up to 80% of the gneiss is sheared and fractured, and groundwater level fluctuations, which show a high degree of uniformity across >200 boreholes. Salt dilution tests indicate flowing fractures up to depths of 90 m below surface, but also highlight zones of low hydraulic conductivity throughout the profile. A lack of vertical or lateral trend in hydrochemistry suggests no significant x-y anisotropy at the catchment scale and distributed recharge across the catchment (rather than from specific lakes or tanks).

In contrast to many areas with crystalline rock aquifers, where lateral connection is poor, sheared crystalline aquifers enable higher abstractions, which can only be sustained through regular local recharge. In this catchment, and probably many similar, abstraction is preventing natural lateral flows (in unpumped conditions) out of the catchment through surface and groundwater, which could have implications downstream. The improved understanding of groundwater lateral and vertical connectivity and processes gained from this integrated study will aid groundwater management in this, and similar, catchments.

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Session Classification : Parallel

Track Classification : Topic 1 - Groundwater assessment and management
Dynamic integration of groundwater and surface water models in an innovative water resources simulator

Tuesday, 24 September 2019 15:30 (15)

The East Anglian region of the UK is a major agricultural producing region of the UK. The region also contains habitats of special environmental interest. It has one of the fastest growing population in the UK. Groundwater contributes over 50% of total water supply in this area. The region is one of the driest areas of the UK and is at significant drought risk with competing demands on the water that is available.

Groundwater is typically represented as a fixed drought deployable output in regional water resource supply/demand system models in the UK. This approach means that it is not possible to operate groundwater and surface water conjunctively in these models. The environmental impact of groundwater abstraction (reduction in baseflow) is not evaluated directly.

Regional groundwater models in the UK provide a tool to assess groundwater availability and baseflow to streams in response to varying climate and demand. However, these models take hours to run and so aren’t suitable for integration into a water resources simulator. Here, we present the creation of ten lumped parameter models (LPM) in Python to represent regional groundwater availability across the East Anglian region. Inputs and outputs from seven regional groundwater models were used to calibrate the LPM. Empirical relationships were used to represent boundary conditions (baseflow to streams, evapotranspiration, flows across the LPM boundaries). Validation of the LPM gave confidence that these reduced-complexity lumped models could perform outside their calibration range.

The LPM were integrated into a larger water resource simulator which was used to evaluate many hundreds of future climate and demand scenarios. The innovative approach allowed the dynamic assessment of regional water availability in groundwater and surface water bodies and the calculation of environmental metrics.

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Session Classification : Parallel

Track Classification : Topic 1 - Groundwater assessment and management
GROUNDWATER RECHARGE AS KEY PARAMETER TOWARDS SUSTAINABILITY OF WATER RESOURCES MANAGEMENT IN LIMPOPO NATIONAL PARK AND KRUGER PARK

Tuesday, 24 September 2019 15:30 (15)

The intent of this study, held in the profile research project SECOSUD II, “Conservation and equitable use of biological diversity in the SADC region”, granted by Italian Cooperation and Development Agency, is to understand the natural regimes of groundwater systems and how water resources are stressed by climatic changes in two sensitive and complex areas of southern Africa: Limpopo National park and Kruger National Park.

Limpopo National Park and Kruger National Park are two of the richest areas in the world from biodiversity point of view. That is why, the priority is to make sure that their water resources are managed in a sound and equitable manner.

After gathering regional and local geological data which allowed to define a detailed geological map of two areas of concern, pointing out the main geological units outcropping, the methodological approach has been to assess the potential infiltration, applying the groundwater Budget Technique performed for the focus areas. Limited to Limpopo national Park, because of the difficult access to meteorological data, they were available the precipitations historical series, referred to the last twenty years of measurements. Otherwise, because Kruger National Park has a historical weather and rainfall monitoring network, they were available the historical series, recorded in the last fifty years, which allowed an elaboration more complete. Relatively Kruger Park, a spatial temporal analysis has been carried on.

In the perspective of analyzing the impact of climate change, we assessed on the first the average precipitation and temperature data referred to the all 50 years of measurements. On the second, the data have been divided in set of 5 years measurements and it was calculated the average annual precipitation and temperature referred to each of the 5-years cycles of data considered. The main purpose is to evaluate a trend evolution of meteorological data to identify potential seasonal changes and which is, depending on them, groundwater system response. On the other it is here presented the methodology applied to make meteorological data available for Kruger Park representative also for Limpopo National Park, in the aim, also, of driving to an integrated management of groundwater in these two areas.

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Session Classification : Parallel

Track Classification : Topic 2 - Groundwater and climate change
An over view on isotopic studies in improvement of the Berrechid aquifer conceptual model

Tuesday, 24 September 2019 16:00 (60)

There is no doubt about the over exploitation of the Berrechid aquifer which spreads on an area of 1500 km², as the piezometric surveys show. This aquifer provides a large part of the drinking water supply and all of that used in irrigation. In deed there is a high demand of agricultural product from the Casablanca city located fifty kilometers away.

Mathematical models have been developed and scenarios proposed. However, the conceptual model suffers from some inaccuracies especially in its component relating to the recharge. The most part of this aquifer is unconfined whereas a small part of it is confined under thick deposits of clays. The matrix of the aquifer is of Plio-quaternary age and is declined in the form of filling deposit with lateral changes of materials thus inducing a great variability of permeability. The substratum consists of formations of different ages with a topography that shows a network of paleo-channels that seems to have been the continuity of the current network located to the south. They are separated from the plain by a fault that morphologically draws a cliff. Structurally, this basin is organized as blocks shaped by perpendicular fault families existing in this geological unit.

The compilation of two isotopic studies, in which measurements of deuterium and oxygen 18 has been carried out, made it possible to draw a number of conclusions (i) a dominance of the phenomenon of evaporation of infiltrated waters which is a characteristic of the semi-arid climate and which is accentuated by the endoreism of the Berrechid plain, (ii) the recharge is also done upstream by the runoff drained by a number of small watersheds which flow into the plain during the winter season, (iii) demonstration of a control of hydrogeological conditions on groundwater flows.

The use of the isotopic tool has brought an additional degree of precision to the conceptual model and consequently to the result of the mathematical one.

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Session Classification : Poster with refreshments

Track Classification : Topic 5 - Tools, methods and models to study groundwater
Decision support tool for the evaluation of potential mar sites: Aquastore

Friday, 27 September 2019 10:10 (15)

Aquifer Storage and Recovery (ASR) and Aquifer Storage, Transfer and Recovery (ASTR) systems have been implemented worldwide during the last 30 years. Despite their benefits and ubiquity, they are commonly designed under the advice of experts with very specific criteria, following their own experience and know-how. In this context, the development of global tools is crucial in order to establish general methodologies for the design and feasibility assessment of this kind of projects, and hence, optimize time and economic resources.

The objective of this tool is to assess the potential feasibility of an ASR/ASTR system by giving the user the most accurate information from the data introduced into AquaStoRe, trying to be practical and maintain objectivity on the final result.

AquaStoRe structure, which was developed on a Microsoft Excel environment, drives the user through 3 stages that evaluate separately socioeconomic, hydrogeological and hydrochemical aspects of ASR systems. The evaluation methodology of those aspects is based on the assessment of 63 indicators, carried out through a multicriteria analysis (MC) that gives to each indicator a value weighted by a specific factor for every indicator. The tool also assesses the reliability of the data used to fulfill the tool requirements.

AquaStoRe went through a calibration process to confirm the correct functioning of every feature. The calibration was performed in two phases: i) the first was the evaluation and updating of indicators’ definitions and ranges by a panel of skilled professionals (Expert Criteria); ii) the second was the calibration of AquaStoRe’s comparison functionality by introducing real data and analyzing the final result.

The final result of this task is a software tool that gives support to decision makers when evaluating the feasibility of ASR/ASTR projects and suitability of ASR/ASTR sites. It synthesizes the relevant information available for each of the alternatives, processes it for the user and creates a series of plots and tables that summarize and evaluate the data of alternative. The results of AquaStoRe give an idea of the strengths and weaknesses of each of the possible alternatives and, moreover, track data gaps and deficiencies on the information and pre-design of the ASR/ASTR project.

As further work, an improvement of the tool incorporating criteria on water safety plan into MAR schemes with regenerated water, as well as hydrogeochemical simulation via Phreeqc-Excel open software has been conceptualized.

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Session Classification : Parallel

Track Classification : Topic 5.3 - Advanced modelling tools for subsurface hydrology: from
the vadose zone to deep environments
Lake Chad is located in the center of an extremely large sedimentary basin (2 million km²), which is filled with neogenous sandy-clay sediments and contains several huge aquifers of regional importance. This study covers the northern part of this basin, an area of 200,000 km² located in Chad. Although this is a very arid area (50 to 400 mm of rainfall a year), it is inhabited by different population groups (2,500,000 inhabitants), whose main source of income is predominantly pastoral livestock farming (the livestock population includes more than 30 million ruminants).

The only surface water resource is Lake Chad and most of the population therefore depends on groundwater for both drinking water and water for their livestock.

Rapid population growth (2%/year) and the rise in sedentary lifestyles are increasing the demand for drinking water. In addition, growing insecurity in the Lake Chad area (Boko Haram) has led part of the Lake Province population to migrate further to the North, where there is no surface water resource.

The plio-quaternary aquifer offers a tremendous opportunity for meeting the growing water demand, as it is shallow, extensive and highly productive (the drilling success rate exceeds 95%). The relatively easy access to this resource makes it vulnerable to overexploitation in adverse conditions: climate change models anticipate a decrease in precipitation and, therefore, in groundwater recharge.

To assess this risk and map this resource, we have used the results of the 1,000 boreholes drilled over the past ten years. We have built hydrogeological maps (piezometry, aquifer productivity, drilling success rates and water quality), and produced economic maps (production costs, operating costs) as these constitute important decision-making criteria in poor regions such as this.

On a regional scale, groundwater flows from south to north, where the aquifer is exhausted when it reaches the wide Bodole depression. The piezometric surface is marked by a series of domes and depressions whose origin, based on their chemical tracers, is discussed in this paper.

For the time being, aquifer recharge by rainfall far exceeds the abstraction rate. However, an increase in aridity and the progressive concentration of people in urban centers, which leads to local aquifer depletion and groundwater pollution, could upset this balance.

The chemical quality of the groundwater varies greatly from one area to another. The south-north salinity gradient has long been recognized and is connected to aridity. Consolidation of the drilling data highlights two other areas with excessive salinity: the western part of Lake Province and the eastern part of Hadjer Lamis Province.

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**Session Classification:** Parallel
Track Classification: Topic 3.1 - Groundwater and water security in developing countries
Transport modelling of Chloridazon-metabolites in soil and groundwater

Thursday, 26 September 2019 16:00 (60)

The occurrence of Metabolites (European Commission 2003) in groundwater resources, which are used for drinking water, has become increasingly the focus of attention in recent years water resource management. Currently, the use of approved herbicidal active substances, their metabolites in increased concentration, which have been detected in 20 water conservation areas (WSG) of Germany are prohibited according to the application restriction NG 301 (BAnz 2018). The prohibition applies mainly on the since 1964 in Germany approved herbicide Chloridazon. It is mainly applied during cultivation of beets but also for beetroot and mangold (chard). Chloridazon degrades into the metabolites desphenyl-chloridazon (B) and methyl-desphenyl-chloridazon (B1) during transport through soil. The Health Related Indication Value (HRIV) for both metabolites is 3μg/l. A coupled flow and transport model of the vadose and phreatic zone is used to estimate the long-term solute concentration in groundwater and the related consequences for drinking water quality of a gravel aquifer used for water supply. Parameterization of the models is based on data from long-term soil monitoring in Lower Saxony, on monitoring data from a drinking water abstraction wells and on published environmental fate properties of Chloridazon and its metabolites. The modelling results show the spatial-temporal evolution of solute concentration and related uncertainty of the model predictions.

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Session Classification : Poster with refreshments

Track Classification : Topic 8 - Groundwater quality and pollution processes
Inspecting methods for conduits tracing and leak detection of water in utility reticulation pipes: case studies in Hungary

Tuesday, 24 September 2019 16:00 (60)

Today, securing, utilizing drinking water reasonably and excluding water loss are drawing multi-sectors’ primary international and national concern. As a result of the ruptures in aging distribution networks, a considerable amount of water loss is challenging the water utilities and authorities. The critically important issue is how to locate leakage among a colossal water mains, of them the contributed pipes are usually made of diverse materials and laid at different depths underground. The present work emphasized some practical geophysical methods for conduits tracing such as: ground penetrating radar (GPR), magnetometer, multichannel resistivity - induce polarization (IP) and electromagnetic locator, drew a comparison between them. Regarding leakage detection techniques, after briefly referring to all of the water loss analysis, pressure management, acoustic methods, and remote sensing-based method, this research recommended some ways to unify these methods. The proposed combination of traditional and novel methods helps elevate the advantages and neglect the demerits of each method, significantly improve the efficiency in leakage detection technique. The paper took a Hungarian as a pilot study, that would be tangible evidence for water leakage detection in Central Euro, one of the most famous area for water resource management. Moreover, the authors have put forward several coherent theories to partly explain possible grounds of this declining water infrastructure that exist all over the world. Several geotechnical factors and possibly relevant geotechnical testing methods are also referred in order to put forward for further studies.

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Session Classification: Poster with refreshments

Track Classification: Topic 10 - Urban groundwater
Impact of the Great Santo Domingo (Dominican Republic) on the hydrogeochemistry of underlying aquifers

Thursday, 26 September 2019 16:00 (60)

Eastern Coastal Plain in the surroundings of Santo Domingo (National District, West Santo Domingo and East Santo Domingo) are urban areas of the capital of the Dominican Republic that are supplied with groundwater and surface water resources. This sources supply about one and a half million people in the capital of the Dominican Republic. During the project "Urban hydrogeology in the aquifer of the Eastern Coastal Plain (National District, West Santo Domingo and East Santo Domingo)" samples from a network of 40 points have been collected in which the unstable parameters have been measured (Temperature, Electrical conductivity, pH and redox potential), major ions (Ca2+, Mg2+, Na+, K+, NH4+, Li+, HCO3-, SO42-, NO3-, Cl-, PO43-, NO2-, F-, Br-), stable isotopes of water (18O, 2H), inorganic carbon (13C) and natural fluorescence of water.

Groundwater quality is affected by the loss of sewage from septic tanks in several districts of the capital. NH4+ has been detected in 50% of the samples with concentration ranges between 0.05 and 9.61 ppm; NO3- has varied spatially between 5.6 and 108.1 ppm, with 40% of samples between 25 and 50 ppm and about 25% above the limit of 50 mg/L established by legislation. The NO3- and K+ have a high correlation, which corroborates the affection of the untreated wastewater in some of the points of the control network.

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Session Classification: Poster with refreshments

Track Classification: Topic 9 - Groundwater and socio-economic development in Latin-America
Environmental and modeling assessments of phosphate processing waste impact on the Skhira phreatic aquifer, South East of Tunisia.

Thursday, 26 September 2019 16:00 (60)

Abstract: Phosphate processing and enrichment in the Skhira industrial zone, located southeastern Tunisia, is inherent to phosphate mining activities of the country but also a major source of serious problems of water resources degradations in the area. For that, the present study aimed to determine the impact of the infiltration of acidic leaching waters charged with various pollutants on the water quality of the Skhira groundwater and to evaluate the extension of plume orthophosphate contamination on the short and medium term. To achieve these objectives a bi-monthly monitoring of water quality was undertaken between October 2013 and October 2014. This assessment targeted the physical-chemical parameters and some trace elements (F, Cd, Cr, Cu and Zn) in order to evaluate the spatial-temporal distribution of contamination, if any. Numerical simulation of water contamination by orthophosphates was performed using the flow and transport model “Visual Modflow software”, developed by Waterloo Hydrogeologic. Results show that the EC and the dissolved salt load increase following the flow direction. This variation is mainly related to water-reservoir-rock interaction, water renewal rate and the infiltration of gypsum waters from phosphogypsum sludge. In addition, the highest H2PO4- contents are recorded in groundwater close to the crude phosphate storage site. The levels of trace elements vary significantly in space and time. Relatively high F- levels would be directly related to infiltration of phosphogypsum leachate, or indirectly related to the emission of fluorinated gases into the atmosphere caused by the phosphate processing factory. After calibration and validation, the model simulated that in 2014, plume of high H2PO4- contents in groundwater have extended 350 m from the crude phosphate storage area with a 10 mg/l contamination front. In 2030, the model predicts that the plume of groundwater contamination by orthophosphates will extend 900 m. It is concluded that prompt and serious measures have to be implemented to stop and hopefully reduce then remove the contamination.

Keywords: phosphate, contamination, groundwater, Skhira numerical simulation.

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Session Classification: Poster with refreshments
Track Classification: Topic 8 - Groundwater quality and pollution processes
Challenges for the assessment and management of transboundary aquifers at the global scale

Tuesday, 24 September 2019 12:15 (15)

A great number of transboundary water systems of the world, including transboundary aquifers (TBAs), support the socioeconomic development and wellbeing of an important part of the world’s population. At present, nearly 600 TBAs have been defined in the Americas, Africa, Asia, and Europe. Transboundary water issues abound and are complicated by lack of adequate governance and shared management. Of upmost importance to resolve those issues are the background assessments, legally-binding agreements and by the fact that in many cases institutional asymmetries do not allow for a standardised knowledge.

We present a critical look at the transboundary aquifer issues, based on the analysis of identified TBAs, and discuss what is working and what it is not to illustrate the most important steps and lessons learned, as well as the good practices needed for water management in the transboundary context.

Our analysis of the current state of knowledge of TBAs in four continents shows that information on most transboundary aquifers remains limited. Given important aspects related to incomplete or contradictory knowledge on TBAs, the large number of stakeholders and opinions involved, scarce legal agreements, and the interconnected nature of these problems with other problems, take us to conclude that groundwater science alone cannot solve transboundary groundwater issues.

In Africa, cooperation on aquifer management has improved, even in the absence of legally-binding agreements. In Asia, TBAs identification, assessment and shared management is still limited. In the Americas, important lessons were learned from the collaborative assessment of some TBAs shared by Mexico and the USA, as well as the Guarani in South America. In Europe, the extension and size of TBAs are generally limited compared to aquifer systems in other parts of the world, the geological complexity in the region and fragmented information, has led to some inconsistencies of methodological approaches to map TBAs.

Issues that still need to be addressed are: hydrogeological understanding of the transboundary systems, clear and unambiguous delineation of TBAs, indicators of cooperation, data harmonization and information sharing and management, and water use conflicts or impacts of global changes in the systems. Addressing these issues requires a concerted effort of all stakeholders involved to establish a satisfactory balance between scientific knowledge and efficient management and protection of transboundary waters.

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Session Classification: Parallel

Track Classification: Topic 3 - Groundwater sustainability and governance
Investigating the productivity of weathered basement aquifers with a synthetic dataset

Tuesday, 24 September 2019 15:15 (15)

Groundwater stored in weathered crystalline aquifers is an essential resource of drinking water in tropical countries. Previous studies based on the analysis of borehole data in African countries have shown that the productivity of these aquifers is generally low (<1 l/s), but there is considerable variability with some boreholes much more productive (> 5 l/s), and other areas unproductive. Although these observed data allow a quantitative estimation of the groundwater resource, they are too sparse to fully explore the factors controlling the productivity of boreholes. In this work, a large dataset from Northern Ghana was used to develop and parameterize a stochastic groundwater flow model to generate and validate a comprehensive set of synthetic yield data. The model was then used to investigate the sensitivity of aquifer productivity with respect to thirteen hydrogeological and borehole construction parameters. These include the thickness, extent, and hydrogeological properties of different horizons in the weathered profile, annual recharge rates, as well as the borehole and water table depths. Groundwater abstraction is simulated with a 2-D stochastic numerical radial flow model accounting for heterogeneous hydraulic conductivity and porosity profiles. These are consistent with traditional geological conceptualisations of weathered basement aquifers. The synthetic dataset yield data was generated from distributions of input parameters comparable to those derived from borehole data in Northern Ghana. The resulting distribution of simulated yields can be considered representative of the actual productivity given the excellent agreement with the real abstraction data. The synthetic data and the corresponding model input parameters were then considered for global sensitivity analysis using the PAWN method. The estimated sensitivity indices indicate that the main factors influencing the average well productivity over a pumping period of four years are: (1) the maximum hydraulic conductivity of the weathered profile; (2) the thickness of the regolith; (3) the static depth of the water table; and (4) the hydraulic conductivity of the unweathered crystalline rock. The average productivity is relatively insensitive to other factors including recharge rates especially if we take into account the contribution of baseflow. However, recharge and aquifer extent become sensitive parameters when we analyse changes in yield over time. Further exploration of higher and lower yielding boreholes within the synthetic dataset reveals variability in the sensitivities to different parameters. This has important implications for siting boreholes for irrigation or small town supplies. The developed approach generates realistic distributions of yields in weathered crystalline aquifers that can be used to estimate aquifer productivity in areas with scarce borehole data. Given site-specific distributions of input parameters, we demonstrate that the model can be used to understand which factors are most important for certain classes of productivity, and the probability of encountering different yields within weathered crystalline aquifers.

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Session Classification: Parallel

Track Classification: Topic 1 - Groundwater assessment and management
Hydrogeology of the Sands, Sandstones and Gravels of the Litoral Alentejo (Portugal)

Monday, 23 September 2019 16:00 (60)

In the past, the hydrogeology of the sands, sandstones and gravels of the Alentejo Litoral were studied only in areas where they occur as one of the hydrostratigraphic units of the Sines and Bacia de Alvalade multilayer aquifer systems, in which they play an important role. We present the hydrogeologic characterisation of these rocks in the coastal area extending from the proximity of Morgavel Dam in the north, to about 5km south of the Cabo Sardão. Porto Covo, Almograve, Cabo Sardão and other smaller towns, are located in this area characterised by the existence of both traditional and intensive agriculture and seasonal tourism, which are the main economic activities in the studied area. As far the authors know, the hydrogeologic studies described in this communication are the first contribution in this field in this extensive area of about 196 km².

In stratigraphic terms the studied lithologies correspond to formations in the Tertiary to Quaternary transition (Plio-Pleistocene) and are deposited at the top of the widespread carboniferous flysch (schists and greywac) formations present on the west coast of the Alentejo Region. As the Paleozoic metamorphic rocks present considerably lower permeability and porosity than the observed values for these parameters in the Plio-Pleistocene sediments, the recharge occurring in the shallow detritic phreatic aquifer cannot be absorbed by the underlying hard rocks. Therefore most of the regional flow generated from recharge at the top of the system is discharged in the sub-aerial and horizontal contact between the detritic shallow aquifer and the carboniferous rocks. These boundary conditions are responsible for the existence of several springs along this contact and, together with the hydraulic connection between the stream network in this area, define the general flow pattern from East to West. The estimated long term average recharge in the studied area is in the order of 26 hm³ (corresponding to 20% of precipitation).

The groundwater flow system was studied through traditional large diameter wells and newly drilled piezometers. Piezometric in situ measurements were complemented with the continuous monitoring of electrical conductivity, depth and temperature (using CTD probes). Hydrochemistry was characterised by in situ measurements of physio-chemical variables (pH and temperature) and water samples for laboratory analysis of major ions and other chemical species. The first contribution to characterise the chemical composition of groundwater in the studied area shows that most of the sampled waters are circum-neutral with very low mineralisation (TDS < 1000 mg/L) and are mostly of sodium-chloride type. Moreover, the results of the hydrochemical characterisation of the studied area shows that the respective typology is clearly distinguishable from groundwater in neighbour formations.

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Session Classification : Poster with refreshments

Track Classification : Topic 1 - Groundwater assessment and management
Assessment of groundwater oil contamination and the development of measures for its localization and liquidation (on the case study of the residential area within St. Petersburg, Russia)

Thursday, 26 September 2019 17:15 (15)

In 2015, in one of the residential areas in the south of St. Petersburg, there was an emergency regional-scale spill of oil products (motor oils, fuels and lubricants) onto the landscape and into the drainage ditches, which then penetrated to the surface water, including Neva river, and groundwater.

Difficult conditions of urban development, landscape features (former land-reclamation systems, former kitchengardens), and the basement of the building where the spill occurred, caused many problems with the assessment of the spill scale and determination of its contours.

This situation was aggravated by scarce filtration properties and high porosity of the host rocks, represented mainly by loams and clays.

As a result of the work at the first stage, the volumes and configuration of oil contamination were assessed, and its main migration routes were determined. Aquifer pumping tests were carried out in water wells, the core of rocks was studied, and groundwater and surface water monitoring program was developed and carried out.

At the second stage, a program for pumping tests of contaminated water was developed. The latest Russian filter technologies of the coalescent nanoporous filters "Cribrol" were used for groundwater purification from oil products.

As a result, the concentrations of oil products were reduced to values below the maximum admissible contents for wastewaters to allow the further water purification on local treatment plant.

The report will consider the geological setting and hydrogeological conditions of the site, the results of water and core analyses, the methodology of the study and liquidation of the oil contamination.

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Session Classification : Parallel

Track Classification : Topic 8 - Groundwater quality and pollution processes
Groundwater flow system of the North China Basin: Groundwater age, heat and flow simulations

Friday, 27 September 2019 11:15 (15)

Groundwater flow systems conceptualized according to topography and/or groundwater table configuration generally assume a near-equilibrium state with the modern landscape. However, the time to reach such a steady state, and more generally the timescales of groundwater flow system evolution are key considerations for large sedimentary basins. In the North China Basin (NCB), there remain contradictions between the generally accepted conceptual model of regional flow, and environmental tracer data. We re-examined a range of isotopic tracer data and conducted new three dimensional groundwater age and heat transport simulations in the NCB, for evaluating the impact of different combinations of hydraulic parameters and boundary conditions on groundwater flux, flow paths, groundwater age distributions and heat transport, and use coupled groundwater flow and solute transport modeling to estimate theoretical maximum groundwater ages under hydraulic conditions. It is more reliable to consider the Quaternary and Neogene aquifers together when evaluating regional groundwater circulation, and more reasonable to view the deep groundwater in the NCB below the central and coastal plains as virtually stagnant, at least on human timescales (i.e., decades) or even longer on thousand-year timescales. The model results show that in contrast to previously accepted conceptualizations, most groundwater is discharged in the vicinity of the break-in-slope of topography at the boundary between the piedmont and central plain. Groundwater discharge to the ocean is in contrast small, and in general there are low rates of active flow in the eastern parts of the basin below the central and coastal plain. This conceptualization is more compatible with geochemical and geothermal data than the previous model. Simulated maximum groundwater ages of ~ 1 Myrs below the central and coastal plain indicate that residual groundwater may be retained in the deep parts of the basin since being recharged during the last glacial period or earlier. The groundwater flow system has therefore probably not reached a new equilibrium state with modern-day hydraulic conditions. The previous hypothesis that regional groundwater flow from the piedmont groundwater recharge zone predominantly discharges at the coastline may therefore be false. A more reliable alternative might be to conceptualize deep groundwater below the coastal plains a hydrodynamically stagnant zone, responding gradually to landscape and hydrological change on geologic timescales. This study brings a new and original understanding of the groundwater flow system in an important regional basin, in the context of its geometry and evolution over geological timescales. There are important implications for the sustainability of the ongoing high rates of groundwater extraction in the NCB. The determination of the spatial distribution of the transition (mixing) zone between the active groundwater system with the deep stagnant groundwater is a challenging topic for future research.

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Session Classification : Parallel

Track Classification : Topic 5.4 - Innovative approaches for understanding groundwater flow systems
Flow and heat transfer numerical modelling in the Hainaut limestone geothermal reservoir: study at local and regional scales

Thursday, 26 September 2019 16:00 (60)

Nowadays, Europe needs to produce more sustainable energy. A possible solution includes geothermal energy. Many sites are already in activity for example in France, Germany or Italy. In Belgium, research is currently performed in the Campine Basin. In the Mons area (South-West Belgium), some wells have been exploited since the eighties. They were drilled in a deep limestone reservoir characterized by some highly permeable breccia levels. This reservoir has not been studied extensively, despite potentially important heat reserves.

In this context, the MOREGEO project has been initiated by the University of Mons and the IDEA (intercommunity active in the area) with financial support from the ERDF European program. The general objective of this project is to drill a new geothermal doublet to provide heat to the largest city hospital. Hot water will be pumped from a well and cold water will be reinjected in another one. Specific objectives of the project include: (1) Modelling heat transfers at the scale of the new geothermal doublet; and (2) Modelling the whole geothermal reservoir in order to provide an efficient management tool for the future development of additional geothermal wells.

The geothermal reservoir of Hainaut is mainly composed of limestone from the Carboniferous period, with breccia and evaporites levels. Three wells currently provide energy for the heat production to two hospitals, schools, station, housings and economic areas. The depth of the exploited layers is around 2000 meters and the pumping groundwater temperature is about 70°C.

A numerical model has been developed at the scale of the future new geothermal doublet with and without heterogeneity. Numerical models are implemented using Hydrogeosphere. This calculation code simulates fluid flow, solute and heat transport in porous and fractured media. The model aims at analysing the conditions of the exploitation, the longevity of the system, and the possible interactions with surrounding geothermal wells. The reservoir includes layers of anhydrites, partly or totally dissolved according to the location.

Simulations show that the parameters expected in the area allow the exploitation of geothermal wells to provide hot water for heating. Cold water injected at the reinjection well goes in the direction of the pumping well, located 1,400 m away. The longevity of the exploitation depends on the time taken by cold water to induce a decrease of temperature at the pumping well. A sensitivity analysis of the model parameters has also been carried out to see which parameters have the most important impact on the exploitation and the longevity of the geothermal doublet system. The results show the influence of the permeability of the exploited rock layer. The thickness of the layer and the flow rate in the pumping and reinjected wells have also to be considered as important parameters.

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Session Classification: Poster with refreshments

Track Classification: Topic 5.4 - Innovative approaches for understanding groundwater flow systems
Nitrate Vulnerable Zone to reduce nitrate pollution in groundwater: the unsuccessful case of Gallocanta groundwater body (Spain)

Tuesday, 24 September 2019 16:00 (60)

Agricultural activities have been recognized as one of the main causes of groundwater degradation worldwide. In the European Union (EU), the Nitrate Directive (Directive 91/676/CEE) set the threshold of nitrate concentration to declare water bodies as affected at 50 mg/l. After that, the states should designate as Nitrate Vulnerable Zones (NVZ) those areas contributing to the pollution. However, several researches have called into doubt the efficiency of this protocol, due to the way that NVZ are designated in some countries, the voluntary basis in the application of the good agricultural practices and the ambiguous interpretation of the action programmes.

In this study, the effectivity of one of the first NVZ designated in order to control nitrate pollution in Spain is assessed. Gallocanta Groundwater Body (GGB) is located within the Gallocanta Lagoon catchment (540 km2) an endorheic basin located in north-east Spain and subject to intense agricultural activity. Due to the high levels of nitrate, a significant section of GGB was declared as affected by nitrate pollution by the water authority. Afterwards, the regional government designated part of the GGB as a NVZ in 1999. This NVZ has been modified in a couple of occasions, being the current extension 208 km2. For this analysis, we compiled available water quality data from 1979 to 2018 (water authority monitoring programs) from 74 stations across the study area. Statistical tests were applied to the 29 stations with at least ten measurements during the study period. In addition, we obtained a proxy of the whole GGB through annual interpolations.

Before 1999, 20% of the stations presented increasing trends (p<0.05), and no decreasing trends were detected. The proportion of stations with increasing trends was 16% after the NVZ implementation, and 21% of the stations presented decreasing trends (p<0.05). Our estimation for the whole GGB showed an increasing trend (p=0.018) in nitrate throughout the study period. Prior to NVZ designation, the estimated increasing trend was 0.3 mg/l per year. After the designation, the estimation is negative (-0.51 mg/l per year), although this value is not statistically significant (p=0.48). Considering actual values rather than trends, we found that 60% of the stations presented nitrate concentrations higher than 50 mg/l in 1999 whereas in 2018, 57% of the stations remained above that threshold.

Even though the rate of increasing nitrate concentration has shown a slight decrease, nitrate concentrations are still high in the area and are expected to remain high in the near future. Our observations are in line with previous studies and help to highlight the inefficiency of the current designation methods for NVZ and/or action programmes implemented to reduce nitrate pollution and comply with the environmental goals of the Water Framework Directive.

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Session Classification: Poster with refreshments
Track Classification: Topic 8 - Groundwater quality and pollution processes
Karst spring discharge evaluation supported by a grey-box data driven based method

Thursday, 26 September 2019 16:00 (60)

Most part of groundwater in Central Italy, as in the whole Apennine Mountains chain, is stored in karst aquifers. In last decades, the most important water resources in Italy are affected by sensitive depletion, mostly due to the increasing of anthropogenic activities and the impacts of climate changes.

In the field of simulation models of hydrological and hydrogeological processes, physical hydrological models are based on physical laws. Data-driven approaches, on the contrary, do not rely, directly, on explicit physical knowledge of the process, but they build a purely empirical model, linking input and output variables. Using various learning algorithms data-driven approaches provide a flexible way to model complex phenomena such as the spring discharge. Many approaches proposed to analyze the relationships between the rainfall time series over the recharge area and the spring outflow. Research studies, concerning karst springs, employed time-series analysis studying transfer function between rainfall and spring discharge, obtained by black-box models. These ones are often based on continuous and discrete wavelet analysis, cross-correlation analysis, or machine learning models, such as artificial neural network.

In this paper, primary factors governing spring discharge patterns related to rainfall input are modeled by a grey-box on data driven model trained by an evolutionary algorithm. The model uses monthly rainfall ($P_{-1}, P_{-2},..., P_{-k}$) and temperature ($T_{-1}, T_{-2},..., T_{-k}$) time series as input data for the evaluation of spring discharges.

The first step of the pre-processing procedure in order to take into account of derived phenomena and the magnitude of the data processed. In addition, in order to take into account the evapotranspiration phenomenon, the temperature values are used in the preliminary non-linear normalization of the effective rainfall.

Input and output data are supposed to be related by a linear relationship having a polynomial form, where the progressive variables, $P_{-i}$, are the previous monthly rainfall data, considered for a best period chosen by the performance on the assumed number of back months.

A long time series of available data (at least 60 months) is necessary for the algorithm training in which monthly average flow rates ($Q_i$) must be known for the first phase of coefficients determination.

Subsequently, the model frees from flow rate values validating the accuracy of discharge estimation on a different time window.

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Session Classification :  Poster with refreshments

Track Classification :  Topic 7 - Karst Hydrogeology
Hydraulic fracturing and Aquifer Management. A dialectical association in potential areas of exploitation of unconventional reservoirs in Colombia

Friday, 27 September 2019 12:15 (15)

In Colombia, many territories have been the epicenter of conflicts generated by extractive activities of diverse nature. This assertion is especially true in the hydrocarbons sector, which, despite being an important branch of Colombian economy, has a great load of social, environmental and economic disturbances that, in many cases, are not adequately known or managed. Although, Colombia’s hydrocarbon production presents a wide spectrum of reservoir classes and conditions, the presence of high WOR (Water-Oil-Ratio) in most of them is a general rule. This feature tends to be increased with improved recovery methods such as steam injection.

In this country, the hydrocarbons industry annually uses 120 million m$^3$ of water in conventional production, however, it is the treatment and disposal of associated water that represents the greater weight, requiring the treatment and disposal of more than 700 million m$^3$ of water. This final disposal is made, mainly, by reinjection in deep aquifers without use for human activities.

Even though existing regulations adopt strict rules and parameters, in some sectors of the population, there is great resistance to the expansion of the production of hydrocarbons, derived from the adverse consequences on surface and underground water resources, attributed to the absence of specific regulations until the emergence of the Environmental General Law (Law 99 of 1993), as well as those caused by accidents, sabotage and damages, produced by anti-technical operations and aggravated by the deficient institutional capacity and knowledge to develop inspection and control activities and, if applicable, punishment for the affectation of water resources and non-compliance of prevention mechanisms.

To this is added the decrease in hydrocarbon reserves, which increases concerns not only about the survival of the sector but also about the country’s fiscal viability. Given this scenario, the boom in the production of hydrocarbons from unconventional reservoirs seems to be an alternative to face these deficit scenarios, however, the fundamental question arises: Is it possible to produce unconventional deposits using hydraulic fracturing and preserving the underground water resource in each of the aspects and phases of the operation?

This presentation addresses the main dilemmas and the necessary considerations for an exemplary environmental management in a possible development of this type of hydrocarbon exploitation in Colombia.

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Session Classification : Parallel

Track Classification : Topic 9 - Groundwater and socio-economic development in Latin-
Investigation of the impact of changed precipitation patterns on groundwater recharge processes in a semi-arid carbonate aquifer by an integrated surface-subsurface, multi-continuum model

Climate change is expected to have a significant impact on the water budget of Mediterranean karst aquifers due to a projected decrease in mean precipitation, while intensity and frequency of short-duration extreme rainfall might increase (IPCC, 2007). Sustainable water management practices require predictive modeling of large-scale groundwater reservoirs on the basis of a sound estimation of recharge rates and a solid understanding of flow and transport processes. Here, we employ the finite element distributed multi-continuum flow simulator HydroGeoSphere (Aquanty, 2015) on a high-performance-computing platform to simulate the hydrological-hydrogeological cycle of the Western-Mountain-Aquifer (WMA). The WMA (9000 km²), located in Israel and the Palestinian Territories, comprises deep buried karst conduits that determine today’s discharge point at the Taninim spring. Submarine depositional and erosional developments during the Oligocene (i.e., formation of canyons as a result of large-scale sliding) as well as further erosion by groundwater and surface water discharge under lowered sea water levels during the Messinian event (~6 Ma) led to the formation of the deep karst conduits. Macroporosity (i.e., fractures and conduits) represent efficient flow paths in karstified rocks, transmitting water under rapid flow conditions, while the primary porosity of the rock matrix provides substantial storage and slow drainage. A double-continuum approach based on the volume-effective Richards’ equation with van Genuchten parameters is applied in order to simulate flow in the variably saturated fractured-porous subsurface, accounting for the duality of karstic flow, both in the vadose and phreatic zones, with rapid flow through conduits and slow flow through the rock matrix. Overland flow due to infiltration excess is accounted for via a 2-D friction-based overland flow continuum, coupled with a first-order exchange term to the subsurface. This allows to naturally account for the partitioning of rainfall into diffuse and rapid direct recharge, e.g., along dry valleys or sinkholes. This modeling approach accounts for complex infiltration characteristics of the rock-soil landscape, with local recharge along karst features and transmission losses of ephemeral streams (wadis) under highly variable precipitation patterns. The model will eventually be employed to simulate water flow under changed hydrologic conditions due to climatic changes and employed as a management tool.

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Session Classification: Parallel

Track Classification: Topic 7 - Karst Hydrogeology
TECHNICAL CONSIDERATIONS ABOUT INDUCED SEISMICITY DERIVED FROM WATERS REINJECTION IN DEEP AQUIFERS

Thursday, 26 September 2019 16:00 (60)

In Colombia, as in other parts of the world, there is a strong debate about the risk of producing seismic events as a result of operations associated with the exploitation of unconventional reservoirs or those related to the elimination of oil waters.

Although the institution that regulates these operations (Ministry of Mines and Energy) has issued the standard 90341 of 2014 that defines technical requirements and effective procedures for seismic monitoring during the exploration and exploitation of unconventional reservoirs and, in it, instructs the project operator to identify and to verify, technical strategies to minimize the induced seismic risk, it has not been possible to provide tranquility to the population due, mainly, to the weak knowledge of the techniques of monitoring, simulation and control in seismic, geophysical, geomechanical and hydrogeological aspects of deep aquifers.

This is exacerbated by gaps in the consideration of the main parameters that govern the earthquakes generation such as: the detailed estimation of the crystalline basement and the identification of suitable sites for injection in addition to the effective control mechanisms for the permanent monitoring of disposal rate of return fluids and production waters, the accumulated volume of these fluids and their association with the seismicity induced in each region.

Systematic observations on the occurrence of earthquakes, carried out for certain periods of time, have allowed to conclude that in the seismic zones the smaller events occur more frequently than the higher energy events. This trend has been quantified through the magnitude-frequency relationship, also known as the Richter-Gutenberg relation, which is expressed as $\log_{10} N = a - bM$, where $N$ is the number of events with larger or equal magnitudes that $M$. In this relation, $(a)$ describes the total number of events, while slope $(b)$ reflects the relative number of large events compared to small events.

This paper presents estimations of $b$ parameter, the magnitude of completeness ($M_c$) and the maximum annual recurrence expected according to the trend of the catalog used by the ZMAP software in the Magdalena Medio region (Colombia), seeking to expand, in this way, the knowledge base that allows adequate planning and decision making support in management of complex problems associated with the conventional and unconventional hydrocarbons industry.

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Session Classification : Poster with refreshments

Track Classification : Topic 9 - Groundwater and socio-economic development in Latin-America
To manage a resource, you must know it. With respect to water, that knowledge refers to the natural hydrological system. Participatory planning models have been born in opposition to vertical planning. Today, there is not only a scientific knowledge that is accepted as true, now it is recognized that the knowledge of those who have inhabited the territory is equally valid and complements the understanding of the natural system, and the dynamics and consequences that are produced on them.

Thus, the formulation and execution of environmental management measures for aquifers can be based on the cultural action of the communities and on the knowledge dialogue that makes possible the transfer of information and the social appropriation of knowledge.

The culture of water is the set of ways and means used to satisfy basic needs related to water and everything that depends on it. This concept includes what is done with water, in the water and by the water to help solve the satisfaction of some of these fundamental needs. It manifests itself in language, in beliefs, in values, in norms and organizational forms, in technological practices, in the elaboration of material objects and in symbolic creations (artistic and non-artistic).

This work presents a group of experiences that have allowed this dialogue of knowledge to be developed as an effective tool in the relations between men and between themselves and nature; as a contribution to the resolution of conflicts generated by water, in some regions of Colombia in which the GIGA research group has developed hydrogeological projects of diverse nature and magnitude.

This work presents a group of experiences that have allowed this dialogue of knowledge to be developed as an effective tool in the human relations and between men and nature; as a contribution to the resolution of conflicts generated by water, in some regions of Colombia in which the GIGA research group has developed hydrogeological projects of diverse nature and magnitude.

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Session Classification: Poster with refreshments

Track Classification: Topic 9 - Groundwater and socio-economic development in Latin-America
Comparison of groundwater recharge under conservation agriculture and conventional practice

Monday, 23 September 2019 16:00 (60)

Up to 70% of the populations in the sub-Saharan countries of Malawi, Zambia and Zimbabwe rely on groundwater resources. Under the pressure of demand for agricultural production in already water scarce regions, and further threatened by drought events, it is important to effectively select agricultural practices that minimize negative effects on groundwater recharge and availability. Over the last two decades, conservation agriculture has been promoted by many sub-Saharan governments and NGOs as a tool to obtain reliable crop yields while increasing soil fertility. Key principles of conservation agriculture comprise minimum tillage and mulching, and previous studies indicate positive effects of these practices on soil moisture balance. However, only limited studies have been undertaken on the effects on groundwater recharge in general, and none of these in the sub-Saharan context.

In this study, we introduce a plot-scale approach with a combination of different measurement techniques to identify differences in recharge patterns between sites under conventional and conservation agricultural practice. By combining these different methods, we want to answer the question if increased infiltration of water into the soil promotes recharge, or if improved water retention in the root zone of the soil increases losses in groundwater recharge in the sub-Saharan environment. The presented setup comprises three experimental sites in Zambia, Zimbabwe and Malawi on which both conventional and conservation agriculture is practiced. Each site is instrumented with soil moisture monitoring probes, automated pressure transducers to log groundwater level fluctuations over time, and time-lapse electrical-resistivity tomography equipment to track soil moisture changes. Environmental isotopes, residence time tracers (such as CFCs and SF6) and water chemistry will be analysed to estimate groundwater age and chemical signatures at different depths.

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Session Classification : Poster with refreshments

Track Classification : Topic 3.1 - Groundwater and water security in developing countries
A method to drive performance in groundwater resources management and protection

Tuesday, 24 September 2019 15:15 (15)

Groundwater resources are threatened in numerous areas of the world, mainly because of high anthropogenic pressures degrading that degrade their quantity (e.g. overexploitation) or their quality. To remediate or, better, to prevent such situations, the fundamental principles of sustainable management and protection (quantity, quality) of groundwater resources are well known. However, often, these principles are often not well mastered by all groundwater users (industrials, farmers, etc.). This issue is amplified by the low cost of the groundwater resource, that doesn’t encourage to pay lots of attention to this commodity, but also by the low level of hydrogeological culture among among the engineers and technicians who day-to-day manage them.

Some industries, such as the water bottling industry, rely quasi-exclusively on groundwater whose quantity and quality directly have a direct impact on their core business. Consequently, the water bottling industry has integrated for a long time hydrogeological competencies into its human resources. It has also developed internal processes to anticipate and prevent any risk related to the good proper supply of groundwater to the bottling factories with groundwater, both as regards quantity and quality. As preventing such issues doesn’t stop at the fence of the factory, most bottling companies have also implemented strong relationships with the local communities, stakeholders, and other water users on in the groundwater watersheds where they operate.

Danone Waters, the water division of the Danone company has the 2nd position worldwide on the packaged water market, by volume. It has developed now since for more than 15 years an internal method, named “SPRING”, to ensure that the groundwater resources it relies on are well managed and protected. This process is now deployed worldwide in all its bottling factories and is designed to be directly implemented at the factory level.

Then, the main objectives of this presentation will be to:

- present and describe the SPRING method, its initial "terms of reference", and also to briefly describe its history and evolution as the result of its operational use in the Danone Waters Division;
- compare it with similar methods, particularly to highlight its specificities related to groundwater resources, as most other methods are more generalist;
- describe how it is operationally implemented in the Danone Waters Division, and the resulting benefits for the company;
- briefly present how this methodology is being transposed, in Indonesia, to other water uses than bottling, outside of the Danone Company;
- discuss these results and propose perspectives for the improvement of the SPRING method, and also for its dissemination, with the overall ambition to contributing to the setting-up of best practices to favor foster the sustainability of groundwater resources.

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Session Classification: Parallel
Track Classification: Topic 3 - Groundwater sustainability and governance
Tracking the origin of SO4-2 enriched karst groundwater at a regional scale (S Spain)

Thursday, 26 September 2019 16:00 (60)

The oxygen and sulfur stable isotopes (δ18O_H2O, δ34S_SO4, and δ18O_SO4) are commonly used in hydrogeological research to decipher the source/s of dissolved SO4-2 in groundwater flows (i.e. application of fertilizers, sulfide oxidation, gypsum rock dissolution, etc.), both of anthropogenic and/or geogenic origin, which is relevant to establish groundwater protection strategies. This study aims to track the origin of karst waters flowing through selected aquifers in S Spain, by contrasting their chemical composition with their isotopic signature (δ18O_H2O, δ34S_SO4, and δ18O_SO4). Additionally, a compilation of regional to international cases studies is reported to refer the results to the isotopic fingerprinting of enriched-SO4-2 karst groundwater worldwide. A field survey was performed for groundwater sampling in carbonate and evaporitic aquifers located in the Málaga province and its neighbor provinces. The analytical results show SO4-2 concentrations ranging from 39 mg/l to 7197 mg/l (oversaturated in gypsum) and variable δ34S_SO4 and δ18O_SO4 composition, from +7.2 to +15.4‰ and from +9.3 to +15.2 ‰, respectively. Most of the studied karst groundwater (>80 mg/L of dissolved SO4-2) are within the reference field of Triassic evaporite rocks of the Betic orogen, which determine the water-rock interactions in the deeper compartments of the carbonate aquifers (Triassic to Jurassic age) in contact with the gypsum-bearing basement rocks or within the evaporitic (Triassic) karst aquifers. In all cases, their isotopic relationship δ18O_SO4 vs δ18O_H2O exclude the sulfide oxidation as the precursor of the SO4-2 contents. On contrast, spring waters impoverished in SO4-2 (<80 mg/L) from carbonate lithologies clearly show anthropogenic influence, based on the mixing with fertilizers and wastewater leachates. In this study, the reported values of oxygen and sulfur stable isotopes (δ18O_H2O, δ34S_SO4, and δ18O_SO4) not only have permitted to discriminate the origin of dissolved SO4-2 of karst groundwater but also to refine the hydrogeological knowledge/functioning of some of the studied aquifer systems.

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Session Classification : Poster with refreshments
Track Classification : Topic 7 - Karst Hydrogeology
Groundwater resource in the Eastern Desert of Egypt represents beside the surface water from the Nile a very important resource. In form of fracture springs, dug wells and relative deep wells groundwater serves as an only source in remote communities and also as a source for the desalination process at the Red Sea touristic facilities. Eight locations in the area of Hurghada (south group), seven locations in the area of Elgouna (mountain group) and nine locations in the area of St. Anthony and St. Paul (north group) were sampled. Chemical composition, stable isotopes of 2H and 18O, tritium 3H were analyzed in all collected samples and additionally helium 3He and 4He was analyzed in the deep wells in the mountain group. The molar ratio Br/Cl indicates influence of evaporates in the north group and marine aerosols influence in the recharge area of the south and mountain group. The results show that groundwater in the south group and the mountain group needs a long time from the recharge area to springs and deep wells. From the recharge area to the springs and wells the residence time is over 60 years. In the mountain group 4He concentrations indicates groundwater ages of several 100 to 1000 years. Elevated temperatures and 3He/4He ratios show magmatic influence through the faults of the Red Sea Rift system. In the northern part where the rainfall is more frequent, the concentration of tritium was between ≤ 0.5-1.5 TU and indicates the residence time between recharge area and springs is shorter and the fractures might be more open. The discharge of the St. Anthony spring, where 3H was less than the detection limit was recorded along a period of four months to investigate the hydraulic behavior of the aquifer. The measurements which were observed till now show a constant discharge rate indicating a regime of old water which takes long flow path from the recharge area to the spring area. On the other hand, the tritium concentration in the other springs which range from 0.5-1.5 TU indicate different independent flow paths which are probably connected with the fault system in the fractured rocks. The constant (even if low) discharge flow of most of the springs depends on a big buffer in the mountains with little change in the hydraulic head. The stable isotopes 2 H and 18O indicate infiltration condition of extreme low humidity. The calculation of infiltration temperature depending on the stable isotopes and the noble gases reflects different values and imply warmer infiltration conditions rather than the one calculated from the stable isotopes. The groundwater management in the Eastern Desert of Egypt must control that discharge from wells is in equilibrium with the rare recharge.
Track Classification: Topic 5.3 - Advanced modelling tools for subsurface hydrology: from the vadose zone to deep environments
Groundwater storage assessment and flow path identification in a large-scale fractured bedrock aquifer system

Monday, 23 September 2019 16:00 (60)

Fractured bedrock aquifers account for 20% of the world’s aquifer systems, yet significant questions of how to characterize and quantify the magnitude of subsurface storage in the context of water supply development remain to be understood. These aquifer types are the only water source for many regions of the world, and it is imperative to understand their hydrologic sustainability under the threat of changing climate. In this work we describe the results of an on-going study to understand the magnitude of groundwater storage and water supply sustainability of one such aquifer system on the island of Tobago. The island is predominately composed of highly fractured Mesozoic igneous and metamorphic rocks with well-developed saprolite soil cover. Prior work has established a robust hydrologic budget of the entire aquifer system, with the major conclusion that the fractured bedrock receives recharge of ~400 mm of the ~1900 mm total annual precipitation. This study aims to use geochemical and environmental tracers to further confirm, constrain, and refine this conceptual framework.

We evaluate the distribution and abundance of solutes provided by both weathered rocks (e.g. saprolites) and non-weathered fractured crystalline rocks during the storage and transport of groundwater. Preliminary results suggest that fractures have provided flow paths and enabled groundwater mixing due to increases of major elements, compounds and stable isotopes from the central northeast region of the island towards the south-southeastern region, across significant topographic watershed divides. This is supported by the observations that groundwater production exceeds calculated recharge inputs in these sub-catchments. Strontium concentration also increases by an order of magnitude towards the southeast creating three distinct water groups: fresh water (87Sr/86Sr ratio range 0.70400 to 0.070750 and 0.05 to 0.50 mg/Kg), fresh water (87Sr/86Sr ratio 0.70450 to 0.70650 and 0.5 to 2.0 mg/Kg) and brackish water (0.70550 to 0.70650 and 2.0 to 5.0 mg/Kg). Stable isotopic measurements of ground and surface water suggest a well-mixed large-subsurface storage reservoir. On-going measurements of tritium, CFCs, and SF6 will establish mean transit times of groundwater that can assist in estimating the groundwater response time of the aquifer under different climate scenarios. Together, this study will established the magnitude of groundwater storage in the complex fractured bedrock aquifer system, which is essential for management of this freshwater finite resource.

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Session Classification : Poster with refreshments

Track Classification : Topic 2 - Groundwater and climate change
The occurrence and movement of groundwater in hardrock terrains are mainly controlled by secondary permeability triggered by fracturing. Mapping and monitoring of groundwater resources and estimation of future resources are key issues in hardrock regions. Conventional methods used to the identification, delimitation and mapping of groundwater potential zones are mainly based on ground surveys using geological, morphotectonics, geophysical and hydrogeological tools. Delineating groundwater potential zones using remote sensing and Geographical Information Systems (GIS) is a rapid and cost-effective tool to generate valuable geo-data. Hydrogeomorphology deals with the interaction of geomorphic processes relating surface water and groundwater, connecting, namely, physical geography, geomorphology, geology, hydrogeology, remote sensing and climatology. Hydrogeomorphology can be applied to the definition of areas of higher infiltration and of higher potential for groundwater circulation. The Infiltration Potential Index (IPI) is reliant on several factors (e.g., lithology, structure, weathering grade, tectonic lineaments, land use, drainage, slope, rainfall) which can be overlapped and cross-linked in a GIS environment. In urban areas, this index should be complemented with anthropogenic and urban hydraulic features, like the water supply, the sewer and the stormwater networks. In the urban framework it is called Infiltration Potential Index in urban areas (IPI-urban).

The aim of this work was to delineate the groundwater potential zones in the urban area of Viana do Castelo (NW Portugal). A combination of GIS and Analytical Hierarchical Process (AHP) techniques was used. This methodology took advantage of remote sensing and hydrogeomorphological mapping, accompanied by a hydrogeological inventory fieldwork. Hydrogeomorphological mapping and 8 thematic layers (land use, geology, tectonic lineaments density, slope, drainage, water supply system, stormwater network and sewerage network densities) were prepared for groundwater potential zones delineation. Weights assigned to each class in all the thematic maps are based on their characteristics and water potential capacity through multi-criteria AHP method. Land use plays an important role: urban and industrial areas cover the largest part (60%). Geology also has a key role: alluvia, fluvial and marine deposits are the most representative (49%) and two-mica granite, medium to coarse grained, is the second more representative lithology (36%). Tectonic lineaments show a density < 4 km/km² for most of the area (72%). Slopes are mostly gentle to very gentle (< 3°, 57%). Drainage density is frequently < 1.5 km/km² (76%). Stormwater network densities are frequently < 8 km/km² (52%). For the sewage network, most of the area has a density < 10 km/km² (53%). The water supply system densities are mostly < 21 km/km² (70%). Consequently, it was possible to achieve a prevalent (70%) Moderate to Low (40–60) IPI-Urban in this study area. This study provides insights for decision makers for appropriate planning and management of groundwater resources in urban regions.

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**Session Classification :** Poster with refreshments

**Track Classification :** Topic 10 - Urban groundwater
Dynamic storage and volumetric filling levels indicating regional groundwater availability

Monday, 23 September 2019 16:00 (60)

Groundwater shortage during drought periods will become more important in future and of relevance even in water-rich regions. Switzerland as considered Europe’s water tower disposes of large groundwater resources in the range of 150 km3, but some problems may arise under extreme conditions, such as in 2018 with dramatic precipitation deficit over more than 6 months. Therefore, additional tools going beyond classical monitoring are needed to better characterize such situations and to improve the knowledge on the state and evolution of groundwater quantity on regional and national scales.

Fluctuations in regional groundwater volume can be used as indicator for actual groundwater availability. An approach was developed accordingly for assessing groundwater volumes, and dynamic storage respectively, for Swiss unconsolidated porous aquifers, corresponding to areas of high water demand. Actual volumetric quantification is deduced from water level records in the framework of the national groundwater monitoring. Those are representative for typical hydrogeological settings, i.e. groundwater regimes, and were linked to static groundwater volume estimates. Upscaling of normalized level amplitudes with respect to long-term mean values thereby allowed for the regionalization of the measurements. This provides complementary online information on the groundwater filling level, i.e. the ratio of volume variation and total volume, which in turn indicates sensitivity to drought.

The spatial pattern of the filling level is of particular interest in low-level situations, and identifies actual and potential areas at risk. The example of 2018 illustrates the decrease and recovery of groundwater volumes in the different regions of the country, many of which are provided with sufficient reserves despite very low groundwater levels reached. The groundwater volume indicator in this context gives useful information for characterizing the impact of drought conditions for the different groundwater regimes. It represents a tool for administrations and water managers to define critical low-level values and to adapt regional groundwater planning. This also implies infrastructural measures, such as the interconnection of differing water resources, in order to ensure water supply today and related to expected climate change scenarios.

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Session Classification: Poster with refreshments

Track Classification: Topic 1 - Groundwater assessment and management
Vulnerability mapping is used for groundwater protection planning, management and decision making, for the identification of areas susceptible to contamination and for public information and education. Groundwater vulnerability assessment is an important basis to fulfill with the European Union Water Framework Directive (EU_WFD) 2000/60/EC. The Portuguese law (D.L. 382/99; L. 58/2005; P. 702/2009) establishes that wellhead protection areas are defined considering the hydrogeological conditions and encompasses 3 protection zones: an immediate zone, usually marked by a fence, where all activities not linked to groundwater exploitation are forbidden; an intermediate zone, where all activities that may contaminate the groundwater, whether by the infiltration of contaminants or by changing the flow paths, are forbidden or at least strictly controlled; an extended zone, where the constraints to activities are still applied but in a less severe way. A vulnerability-based approach for delineating groundwater protection zones around springs in fractured media may be developed with several methods, namely the DISCO index. DISCO index is normally applied in case of vulnerable springs linked to a highly heterogeneous aquifer and includes the characterization of the hydrogeological properties of the aquifer (DIStcontinuities parameter) and the thickness and permeability evaluation of the protective cover (protective COVer parameter).

This work aims to propose the delineation of protection zones of the main discharge area of a granitic system located in an urban area of NW Portugal. The main spring constitutes one of the most important groundwater resources of the area and its flow rate displays a strong annual variability in the range 35-70 m3/day. The interest for this area is related to its availability of groundwater resources, to contamination issues and to the recovery of the old water system of natural waters for the water supply to the main gardens and fountains. To fulfill this goal, and taking advantage of a GIS (Geographic Information System)-based mapping, interactive geo-databases were created to organise and analyse all the data, namely: topography, land use/land cover, geology, morphotectonics, hydrogeology, climatology, urban hydraulics and sanitation, as well as an inventory of surface and shallow groundwater potential contamination activities. Moreover, several groundwater vulnerability maps were outlined recurring to GOD, DRASTIC-Fm, SINTACS, SI and DISCO indexes.

This study may be integrated as a tool in an urban territorial planning for a sustainable development.

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**Session Classification:** Poster with refreshments

**Track Classification:** Topic 10 - Urban groundwater
Equalising flow in water wells: from theory to practical results

Friday, 27 September 2019 12:00 (15)

Well ageing processes (loss of yield, sand pumping, turbidity, mineralogical incrustation and bio-fouling) are related to a non-uniform, high flow regime in the well. In that communication we review flow equalisation, a technique which counteracts non-uniform flow pattern, and present results from several experiences with Spanish water wells. In this study previously published results for equalisation were reproduced and equalization’s applicability was extended to highly incrusted wells. In a time when economic and environmental aspects lead to increasing interest in well rehabilitation techniques, equalisation deserves attention for its results in the improvement of well hydrodynamics and reduction of well ageing processes.

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Session Classification : Parallel
Track Classification : Topic 5 - Tools, methods and models to study groundwater
A new method to quantify groundwater flow direction at multiple depths simultaneously in a bedrock aquifer is demonstrated. The method utilizes the variable flow rate distribution around a pumping borehole at discrete depths in a bedrock aquifer with natural gradient flow. In such a system, there is generally an increase in flow rate up-gradient, and a decrease in flow rate down-gradient of the pumping well relative to the pre-pumping (natural gradient) conditions. Changes to groundwater flow rates in the aquifer can be detected with fibre optic Active Distributed Temperature Sensing (A-DTS) in multiple boreholes surrounding the pumping borehole, from which, the direction of natural gradient flow can be estimated at many different depths. The method was field tested at the Fractured Rock Observatory on the University of Guelph campus consisting of nine closely spaced boreholes across a 75 x 75 m area drilled to a depth of 73 m below ground surface. Two A-DTS tests were conducted in four observation boreholes under different hydraulic conditions: (1) when all boreholes were sealed with flexible fabric FLUTe liners to measure natural gradient flow rates without pumping, and (2) when the borehole in the centre of the cluster was open and pumped at a constant rate. The observed changes in flow rates at multiple depths were used to estimate the direction of natural gradient flow using a linear regression technique. The A-DTS derived flow direction matches the horizontal hydraulic gradient direction determined from depth-discrete hydraulic head at similar depth intervals. The approach shows excellent potential for efficiently providing both the magnitude and direction of groundwater flow at all depths simultaneously in a suite of boreholes in bedrock aquifers.

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**Session Classification**: Parallel

**Track Classification**: Topic 5.4 - Innovative approaches for understanding groundwater flow systems
HYDROCHEMISTRY ASSESSMENT OF URBAN GROUNDWATERS OF BELEM, BRAZIL

Tuesday, 24 September 2019 16:00 (60)

Groundwater is the major source of urban water supply for Belem metropolitan region, which is the second largest capital of the Brazilian Amazon with a population of approximately 2,300 million inhabitants. Because hydrochemistry assessment of groundwater is critical for Belem region urban water planning, over 160 tubular wells were used for the metropolitan water quality study, encompassing two aquifer units - Barreira and Pirabas. The unconfined Barreiras aquifer consists of Pliocene-Pleistocene/Late Miocene siliciclastic sediments overlying the calcareous Pirabas Aquifer of Miocene age. Salinity is less than 100 μS/cm and pH does not exceed 5.5 in the Barreiras aquifer, whereas those of Pirabas are greater than 100 μS/cm (up to 400 μS/cm) and pH above 7. The contrast in chemical composition can be clearly observed in the Piper and Stiff diagrams. Barreiras aquifer groundwater is dominantly sodium-chloride type and calcium-carbonate is the dominant type of Pirabas Aquifer. Presence of nitrate in the Barreiras shallow aquifers is closely associated with the population density and the scarcity of sewage system. High concentrations of dissolved iron are commonly found in the upper portions of Barreiras aquifer and are related to reduction of iron coating minerals by contaminated waters.

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Session Classification: Poster with refreshments

Track Classification: Topic 10 - Urban groundwater
Groundwater flow modelling through a karst aquifer using four different numerical approaches

Thursday, 26 September 2019 16:00 (60)

Dilution in karst media processes produces double permeability: intergranular matrix and small fractures, and another in the network of conduits, cavities and fractures of greater size. Consequently, double permeability karstic groundwater flow may present a double behavior: laminar in the matrix and turbulent in the conduits. There is also an exchange of flow between both mediums (matrix and conduits), specific to each case, variable in space and time within the same aquifer and very dependent on boundary conditions and on the conductance between the matrix and the conduits. As a result, hydrodynamic response of the double permeability karstic media is difficult to predict and may differ much of the response that would give a continuous means of equivalent permeability.

The aim of this work is to simulate groundwater flow through a karst aquifer located in Sierra de las Nieves, which is a high relief Mediterranean karst placed in southern Spain. The geometry of the aquifer has been previously developed using fractal methods applied to the karst massif (Pardo-Igúzquiza et al. 2016), providing a suitable geometrical approximation of the aquifer conduits path, adequate for the purpose of the present work.

We will test four different numerical approximations to model the study site, three distributed models and one aggregated:

1. MODFLOW-CFP (Shoemaker et al. 2007), that is a package implemented in MODFLOW to solve the non-darcian turbulent flow equation and the laminar regime, coupling the conduit system with the porous matrix.

2. KARSTFLOW (Pardo-Igúzquiza et al. 2018), which is a finite difference program that solves the groundwater flow equation in saturated media and the Richards equation for the unsaturated zone with a gravitational vertical flow (i.e. there is no horizontal components). The flow within the conduits is given by direct recharge.

3. TRANSIN (Medina et al. 1996) is a finite element code developed by the Polytechnic University of Catalunya to solve 3D double porosity saturated flow and transport.

4. VISUAL BALAN 2.0 (Samper et al. 2005) is an aggregated model which allows running a sequential water balance for the soil, the unsaturated zone and the aquifer.

Results predicted by the four models are compared with available flow groundwater measurements at the Genal spring.

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Session Classification : Poster with refreshments
Track Classification: Topic 5.4 - Innovative approaches for understanding groundwater flow systems
Outreach and public education strategies to achieve science based groundwater management policy

Groundwater governance is a complex process involving the collective influences of opinion on policy and management. Achieving sustainability of water supply from aquifers is a major management challenge worldwide that is impacted on the supply-side by changing weather patterns, loss of groundwater inventory because of current and legacy contamination, and because of past over-exploitation. On the water supply demand-side, managers have to balance allocation decisions to satisfy the needs of changing demographics, ecological requirements, water rights and entrenched vested interests.

Science-based decisions should be the foundation of groundwater sustainability policies and the basis for regulatory frameworks to achieve safe drinking water supply. Groundwater specialists should be in the forefront of helping with scientific awareness and technology transfer endeavors to end-users, citizens, community leaders, regulators and elected officials. The public needs help navigating the minefield of information and misinformation about groundwater resources. This paper examines some current groundwater issues in America and outlines strategies that provide groundwater professionals with an objective platform to influence "opinions" included in the discussion will be the problem of groundwater legacy contamination from PFAS (per- and polyfluorinated alkyl substances). As more evidence emerges about the extent of PFAS contamination, the public in affected areas has growing concerns. With impartial guidance to help frame the issues, outreach strategies can communicate solution-based information to inform opinion by combining private sector-expertise, legal perspectives, regulatory authority, and local community representation in single event platforms.

An additional focus for the discussion will be the education and outreach approaches that can help achieve policies to solve the impacts of aquifer overdraft. An education route to achieve sustainability is for groundwater professionals to engage with stakeholders and decision-makers who are not professionally in the water sector. The key to achieving science based groundwater management policy is to make groundwater understandable to policy-makers (elected representatives), groundwater end-users (stakeholders), organizations and interest groups, the news media and people active with social media.

In the traditional top-down approach to managing groundwater the "experts" knew best what was required. The contemporary bottom-up approach requires a broad base of support. Direct involvement in education and outreach by groundwater professionals can help achieve data transparency and jargon-free explanations of the science of groundwater. The presentation considers ways in which effective outreach can assist positive outcomes for sustainability.

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Session Classification : Parallel

Track Classification : Topic 3 - Groundwater sustainability and governance
Tritium (3H) to understand groundwater recharge processes and flow regime of intensively exploited aquifer of northwest India

Friday, 27 September 2019 10:25 (15)

The recent trend of groundwater depletion in north western part of the Indo-Gangetic basin in India has posed serious threat to sustainability of the groundwater resources and the livelihood depending on it. Therefore, it become necessary to understand the groundwater dynamics of the region for proposing a sustainable groundwater management strategy. We analyzed tritium (3H) of groundwater alongwith source water (i.e., rainfall, groundwater, and surface water) to monitor the spatial and depthwise variability of 3H in the aquifer system of the Ghaggar River Basin (GRB). GRB lies between the snow and glacier fed Yamuna and Sutlej river systems of the north-west India. Total 91 groundwater samples were collected from the GRB during pre- and post-monsoon periods of 2013 and analysed at National Institute of Hydrology, Roorkee, India. Results are reported in Tritium Unit (TU) with 2 sigma error. The main objectives of the present work is to trace recharge sources and zones, flow regime and to understand relative residence time of aquifers up to sampling depth of 320 mbgl in GRB of north-west India.

Variation of tritium concentration in the groundwater of the study area was estimated between ~0.10 TU (minimum) and 12.9±0.5 TU (maximum). The groundwater samples collected up to depth of 80 mbgl show significant spatial variation in the tritium values, in the range of 0.3±0.2 to 12.9±0.5 TU. In contrast, the groundwater samples from the aquifers below 80 mbgl (deeper aquifers) in general show lesser variation in the range of ~0.1 to 4.4±0.2 TU. These subtle differences in TU values in longitudinal as well as deptwise indicate complex recharge sources in the study and flow regime in both shallow and deeper aquifers. The comparatively higher tritium concentration in shallow aquifer (depth up to 80 mbgl) has been attributed to the influence of local recharge from the canal seepage and irrigation return flow in the study area. The range of tritium concentration of shallow aquifers indicate that the aquifer is a mixture of modern and recent recharged water. However the presence of low to moderate tritium (less than 4 TU) in deeper aquifer suggest presence of mixed recharged water from recent and old water. The presence of high tritium concentration in middle and distal part of the aquifer in the basin may be due to nested flow system where both young and old groundwater are present at the local scale. It elucidates that aquifer is heterogeneous in nature. The understanding of the variation in the recharge sources, processes and flow regime in aquifer system in the study area can be used for developing a sustainable groundwater management plan for the Ghaggar River basin.

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Session Classification: Parallel
Track Classification: Topic 5 - Tools, methods and models to study groundwater
Analysis of the water turbidity in karst springs from S Spain and its relationship with other natural responses

Thursday, 26 September 2019 16:00 (60)

Despite of a wide monitoring of the natural responses of karst springs have been performed during years to obtain reliable information about functioning of the aquifers they drain, less is known on the significance of turbidity signal to infer hydraulic properties in this media. The carbonate aquifer of Sierra de Ubrique (30 km²), located at SW of Spain, constitutes a strategic groundwater reservoir for its position in the North of Cadiz Province. Recharge of the ~ 500 m thick Jurassic carbonate aquifer, strongly fractured and karstified, takes place by direct infiltration of rainwater, although in high rainfall periods, surface runoff water generated over the low permeability outcrops is directly infiltrated through several swallow holes. Groundwater discharge carried out along the southwestern edge of the aquifer, through multiple overflow springs and two perennial spring, used for drinking water supply of Ubrique city.

In this research, single measurements and hourly monitoring dataset relative to rainfall and the natural responses (discharge and turbidity) of two perennial springs and the most significant over flow spring, have been coupled and used to assess the hydrogeological functioning of the system. All the studied springs could be considered conduit flow type predominantly. The rainfall produce an increase of the flow rate and turbidity of springwater. However, calculated time lags (determined as the time between the input signal and the maximum values of discharge and turbidity) has permitted to detect significant differences in the aquifer functioning under distinct hydrodynamic conditions. This variability depending on the magnitude and amount of rainfall events, as well as other factors such as the karst development. When rainfall was significantly intense, the arrival of recently infiltrated water at the springs causes a turbidity peak occurs while the waterflow is still increasing. This hydrogeological behavior indicates that the aquifer sector drained by the springs has a well development of karstification, with low capacity to attenuate the input signal. The turbidity peaks (recorded before of maximum discharge peaks) would be due to the mobilization of sediments in the conduits, by increasing flow velocities and turbulence as a result of rainfall events. The use of indicators as rainfall amount, intensity of precipitations, previous hydrodynamic conditions and their relationships with the time lags, is useful to characterize the hydrodynamic functioning and provide early warnings and mitigate the impact of turbidity in water supply system of the city of Ubrique.

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Session Classification : Poster with refreshments
Track Classification: Topic 7 - Karst Hydrogeology

Tuesday, 24 September 2019 16:00 (60)

In the Great Metropolitan Area (GAM) of Costa Rica, 65% of the population, equivalent to 1.7 million people, is supplied by the most important volcanic aquifers in the country: Barva, phreatic and the most superficial, Colima Superior, and Colima Inferior, both phreatic in some sectors and confined in others. The GAM has the highest urban and industrial growth and, in addition, agricultural activities related to the intensive use of nitrogen fertilizers. About 70% of the population use septic tanks for the disposal of domestic wastewater and, in most cases, these systems lack the appropriate technical specifications in their construction. Due to the risk of contamination to which the groundwater is exposed, this research aimed to evaluate temporal trends in nitrate concentration in Barva, Colima Superior, and Colima Inferior aquifers. In total, 43 sites have been monitored, some from 1988 to 2018 (1,388 observations). Samples were analyzed in the Environmental Hydrology Laboratory, Universidad Nacional, Costa Rica, quarterly.

Of these sites, 42 exceeded the reference level of 0.1 mg/L of NO₃-, found in a spring in the high lands of the Barva aquifer, an area covered by forests and grasslands. At middle and lower elevations of this aquifer, coffee crops and urban use dominate; average concentrations averaged between 12 and 75 mg/L of NO₃-, with maximums of up to 110 mg/L. Wells that extract a mixture of groundwater from Barva and Colima Superior presented average concentrations between 5 and 44.5 mg/L of NO₃-, while the sites that extract water from Colima Superior and Colima Inferior showed averages between 2 and 24 mg/L of NO₃-, with a maximum of 39 mg/L.

Of a total of 29 sites that extract water from the Barva and from a mixture of Barva and Colima Superior, 18 exceeded 25 mg/L of NO₃-, each one up to 106 times, while five sites exceeded the Maximum Value of 50 mg/L of NO₃-, each one up to seven times. Based on the Mann-Kendall test, a temporary increase was found in 13 sites extracting water from Barva aquifer. There is larger nitrate pollution in areas close to coffee plantations and urban use, due to the use of nitrogen fertilizers and septic tanks. Permanent monitoring of nitrates and other pollution indicators is necessary to support the establishment of regulatory policies on a national scale, focused on reducing nitrates loading to groundwater.

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Session Classification : Poster with refreshments

Track Classification : Topic 8 - Groundwater quality and pollution processes
Innovative coupling between GEOMODELR, FEFLOW and MODFLOW to generate unstructured and prismatic meshes with complex geological models for groundwater

Geomodelr is an online platform for geological modeling that allows visualizing the disposition of different geological, hydrogeological, lithostratigraphic and/or structural units in an interactive and three-dimensional way. Its flexibility allows the generation of 3D hydrogeological conceptual models that can be exported to FEFLOW and MODFLOW regardless the complexity of the project using an adaptive approach or “Smart-layering” or full “Unstructured” conditions to build the geometry. Besides, during geological model construction, the user can include rivers or wells and create meshes with automatic assignment of hydraulic properties (i.e., K, Ss) with element and node selections and local refinements generated in the domain. To achieve such objective, we will implement a model applied to a real case in Úmbita, Boyacá, Colombia, where the geology is complex due to the structural system and lithologies in the zone. Our results show that the geometry built in Geomodelr satisfies the interpretation of the geologists, and the mesh exported keeps with great precision the geometrical forms facilitating the job of the hydrogeologist when generating groundwater numerical models with high-quality.

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Session Classification : Parallel
Track Classification : Topic 5 - Tools, methods and models to study groundwater
Conceptual hydrogeological model of the Rio Grande watershed, Alajuela, Costa Rica using hydrogeochemical and isotopic tools

Thursday, 26 September 2019 15:45 (15)

The Rio Grande watershed is located in the western of the Central Valley, Costa Rica, it covers an area of 634.4 km², with a population of 150,000 inhabitants. The main economic activities in the area are coffee and sugarcane production as well as vegetables and ornamentals. The geology of the area is mainly composed by volcanic rocks with ages from Neogene to recent, but there are also some Pleistocene lacustrine deposits in Palmares and San Ramón, Alajuela. Regional basement outcrops of the Aguacate Group are located on the right bank of the river and include basaltic to andesitic lava flows interlayered with breccias, ignimbrites, and tuffs of Neogene age. Thick volcanic sequence related to the stratovolcanoes of the Central Volcanic Range overlays these rocks. On the left bank, the basement is represented by the Colima formation, composed by lava flows and breccias that are exposed in the east-striking Alajuela fault. Those rocks host fractured heterogeneous aquifers of low to medium potential.

Two groundwater flow systems were identified. The shallowest one is located above an elevation of 1200 meters above sea level, on the slopes of Poás and Barva volcanoes. Most of the sampled springs belong to this group. It is characterized by fast circulation through recent volcanic deposits. The intermediate flow converges toward the Colorado River. At the eastern side, groundwater flows to the southwest, at the western side, it flows to the southeast.

The chemical composition of groundwater reflects the geochemistry of the geological formations with small variations due to dilution and concentration processes. In general, the chemical composition of groundwater is a bicarbonate calcium type with some local variations. Stable isotope signature of the groundwater of the wells and springs evidence a direct recharge. It can be deduced that the aquifers present a short residence time, because lack isotopic variations between the two periods compared.

The stable isotope information shows the altitude effect in the study site, where the water recharged at higher elevation is more depleted in oxygen 18 and deuterium than waters recharged at intermediate and low elevations. From the excess of deuterium it can be deduced that La Laguna de Fraijanes, and the Chayotera and Prendas springs, located in the corridor between the Poás volcano and the Barva volcano, has a similar footprint of Atlantic rainfall. In the western side of the study area, in the town of San Ramón, a well without tritium was found, which indicates that it is the oldest water in the area (<60 years), which could correspond to a regional flow.

The regional conceptual model provides information to public institutions related to water resources, water operators and local governments to establish land planning programs and regional protection policies.

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**Session Classification:** Parallel

**Track Classification:** Topic 5.4 - Innovative approaches for understanding groundwater flow systems
Groundwater is an essential resource for many rural communities in British Columbia, however also municipal water systems rely on groundwater (albeit often in conjunction with surface water). In British Columbia, after the Water Sustainability Act (WSA) came into effect (February 29, 2016), the need and requirement of (better) groundwater management has increased not only from a water allocation point of view but also from a water system planning point of view to ensure that future water demand can be met with the available water resource.

Three years into the WSA implementation, some challenges have been identified regarding groundwater licensing and managing groundwater resources. Stock is being made of what are the lessons learned and how to move forward.

Clearbrook Waterworks District (CWD) is a water utility located in southwestern British Columbia and serves a population of about ten thousand people (regionally and internationally known for its award winning drinking water). CWD solely relies on groundwater for water supply and extracts water from the Abbotsford-Sumas Aquifer, a transboundary unconfined aquifer composed of glacial outwash deposits.

Supervisory Control and Data Acquisition (SCADA) has become an integral tool for CWD for managing groundwater and their well systems. Over the years, CWD has developed a comprehensive natural asset monitoring and management program (with the aquifer being the natural asset). With the help of SCADA a methodology has been developed for analyzing and interpreting groundwater levels and groundwater discharge and recharge trending over the years as observed at CWD’s production and monitoring wells.

By using SCADA for groundwater monitoring, aspects such as well interference from third party wells is better understood as well as the possible effect of winter snowfall (or lack thereof) on aquifer recharge. The analysis of SCADA data has also provided insight in the possible effect of increased annual groundwater withdrawal volumes and changes in pumping regimes on groundwater levels and groundwater balance, information of which is relevant for determining the overall effectiveness of groundwater management strategies that are in place.

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Session Classification : Parallel

Track Classification : Topic 1 - Groundwater assessment and management
Spatial and statistical analysis of factors influencing groundwater vulnerability on the study area of the Gömör-Torna Karst (Hungary and Slovakia)

Thursday, 26 September 2019 17:30 (15)

The Gömör-Torna Karst (known also as Aggtelek Karst and Slovak Karst) is an unconfined trans-boundary aquifer located on the border of Hungary and Slovakia. Thanks to its complex natural heritage, which includes surface karst forms, caves and sinkholes, the region is under the protection of the Aggtelek National Park and the Slovak Karst National Park. The aquifer consists of karstified Triassic carbonates, partially covered with Quaternary clayey sediments. The karst springs provide the drinking water for the inhabitants of the area. The high sensitivity of these resources thus requires an effective and accurate protection strategy.

In the past decades, the Gömör-Torna Karst was in the focus of numerous studies, including hydrogeological investigations and local-scale groundwater vulnerability assessments. For the significant springs of the area records of long term daily observations (1964-1993) are available. This detailed hydrometeorological database provides an appropriate base for data-driven analysis of the factors influencing groundwater vulnerability.

The Weights of Evidence (WofE) technique is a well-known spatial statistical method successfully applied for mineral exploration, landslide hazard zonation, groundwater productivity potential or vulnerability assessment. WofE is a method based on the Bayesian conditional probability, which enables observations of the individual role and the combined effect of different geological, geo-physical or geochemical features to assess the spatial distribution of a natural phenomenon.

Here, we attempt to apply the WofE technique for: i) the evaluation of factors influencing the spring distribution in the karst area and ii) the assessment of a reliable groundwater vulnerability map. The spatial statistical analysis can provide a reliable support in the evaluation of geological and hydrogeological factors influencing groundwater vulnerability in the karst system.

This result is part of a project that has received funding from the European Union’s Horizon 2020 research and innovation programme under grant agreement No 810980.

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Session Classification : Parallel

Track Classification : Topic 5 - Tools, methods and models to study groundwater
Composition of Pore Waters of Lake Baikal Bottom Sediments Sampled at the Gorevoy Utes Hydrocarbon Fluid Seepage Area

Tuesday, 24 September 2019 16:00 (60)

International expedition of the Class@Baikal project took place on the Lake Baikal in 2018; bottom sediments and surface waters were sampled within the Gorevoy Utes hydrocarbon seepage area. The pH and Eh of the "bottom sediments - pore waters" system were measured immediately after opening the sampler. Then, the composition of bottom sediments, surface and pore waters were analyzed in the laboratory.

The Lake Baikal surface water has bicarbonate-calcium composition with low salinity (up to 125 mg/l). Clay minerals, quartz, plagioclase, K-feldspar, pyrite, gypsum are found composing the bottom sediments. Carbonate minerals are not detected. The sediment cation exchange capacity is up to 32 mg-eq/100g and depends on the clay mineral content and composition.

The pH changes with depth from 7.06 to 5.5 and is related to increase in CO2. Eh decreases with depth due to limited oxygen supply from lake waters and oxidation of organic and inorganic components of the sediments (diatoms, CH4, etc.).

The studied pore water macro-component composition differs radically from the surface water composition and pore waters of areas not related to intensive fluid-discharge. It is characterized by high salinity (up to 2 g/l), abundant sulfates, calcium, and magnesium. Sulfate reduction is almost totally missing in these sediments. In areas without fluid seepage pore water composition is bicarbonate-calcium and inherits the lake’s surface water composition. Low mineralization (less than 150 mg/l) is characteristic for the pore waters as well as sulfates are virtually absent due to biological consumption for organic matter oxidation (Pogodaeva et al., 2017).

Isotopic composition of the pore waters indicates their meteogenic origin (δ2HVSMOW from -127‰ to -125.5‰, δ18OVSMOW from -16.3‰ to -17.7‰). In pore solution a presence of bromine (to 0.26 mg/l), boron (to 1.1 mg/l), iodine (0.004 mg/l), abundant rare-earth elements (REE) (over 400 µg/l) are found. The light REE excesses over heavy for all pore water samples and positive europium anomaly is determined in some.

Probably, deep ground-waters discharge together with hydrocarbon fluids through the sediments in the Gorevoy Utes, forming anomalouse composition of pore water. It is resulted also in unusual authigenic gypsum formation in bottom sediments. Presence of gypsum was forecasted with thermodynamic calculations in PHREEQC software and, then, confirmed by XRD analysis of the sediments (up to 5 wt.%).

The anomalous pore water composition in the areas of gas-hydrate formation and oil seeps is known (Pogodaeva et al., 2017). However, pore water with high salinity (up to 2 g/l) is found in the study area for the first time.

References:

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Session Classification : Poster with refreshments

Track Classification : Topic 8 - Groundwater quality and pollution processes
Geochemistry and genesis of Fluoride in drinking water sources of rural areas of Parbhani district, Maharashtra, India

In rural areas of Maharashtra 85 % drinking water sources are based on groundwater. The unplanned and nonscientific development of groundwater resources has led to an increasing stress on the available resources. Hence the adverse impacts can be observed in the form of quality deterioration. The drinking water samples from various dugwells and borewells from rural areas were chemically analysed for water quality. In Parbhani district samples analysed from year 2015 to 2019 it is found that drinking water samples analysed chemically in year 2016-17 are free from fluoride and samples chemically analysed in year 2015-16, 2017-18 and 2018-19 it is found that 26 samples have fluoride concentration more than 1.5 ppm. It is also found that there is variation in concentration of fluoride in drinking water. The area is mainly occupied by the Deccan trap basalt flows. High concentration of fluoride is observed in deeper aquifers predominantly than shallow aquifers and it is also found that the samples showing fluoride predominantly during the premonsoon period when the water level is at deeper level. The physicochemical conditions along with prolonged groundwater residence i.e. lithological groundwater interaction is inferred to be responsible for increasing fluoride concentration in groundwater.

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Session Classification : Parallel

Track Classification : Topic 8 - Groundwater quality and pollution processes
Villafáfila lakes locates in the valley of the Salado river (Zamora, Spain) which develops on Cenozoic sedimentary rocks of the Duero basin. The lakes are 10 to 20 cm depth and commonly become dried out during the summer. Lake mean temperature is 11.8°C during the winter and 19.4°C during the summer and the electric conductivity varies from 4000-5000 µS/cm respectively. Calcium-magnesium bicarbonate waters with low salinities (400 mg/l of TDS) have been identified in wells located in the surrounding hills. At the toe of the hills dominate sodium bicarbonate-chloride waters with salinities about 900-1300 mg/l of TDS. Sodium chloride waters with salinities about 2500-3250 mg/l occur in deep wells (depths > 40 m), lakes and in the springs surrounding the lakes. During the summer the groundwaters below the dried out lakes reaches electric conductivities about 19000 µS/cm, and halite efflorescences occur in the lake plains.

Villafáfila lakes are close to the western margin of the Duero and regional piezometry shows that groundwater flow comes from the northeastern part of basin and further away from the Cantabrian mountains in Palencia province, 150-200 km away from Villafáfila. Wells opened at different depths in the same aquifer suggest that there is a vertical ascendant component in the groundwater flow. Sodium chloride waters from deep wells are considered the regional flow that discharge in the Villafáfila area. The oxygen and hydrogen isotopes evidence that these groundwaters were precipitated in an elevated mountain area. The detrital character of the northern part of the Duero basin and the apparent lack of evaporites in this area points towards a solute acquisition in the catchment of the Cantabrian mountains where Triassic evaporites crops out. The proximity of elevated blocks constituted by low permeability metamorphic rocks are responsible of the groundwaters upwelling in the Villafáfila área.

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US Geological Survey Groundwater Studies in Latin America

The U.S. Geological Survey (USGS) is currently expanding its strategy for international water resources engagements to be more strategic, with the goal of improving our scientific understanding of the hydrosphere. The USGS currently works with several Latin American countries on groundwater resources studies. For example, USGS is working jointly with Costa Rica’s Ministry of Environment and Energy (MINAE) on a National Groundwater Exploration and Assessment Project, combining remote sensing with climatologic, geologic, hydrologic, and geophysical data for identifying areas of high potential for groundwater development. Along the U.S.-Mexico border, the USGS is working with the International Boundary and Water Commission (IBWC) and the Comisión Nacional del Agua (CONAGUA) on the Transboundary Aquifer Assessment Program (TAAP) including the Hueco Bolson and Mesilla Basin in Texas and New Mexico, and the Santa Cruz and San Pedro aquifers in Arizona. In Bolivia, the USGS and Texas Tech University are studying groundwater in the Tolomosa Basin in the Tarija Department with Universidad Católica Boliviana, and UCB’s connections to Cooperativa de Sistema de Agua y Alcantarillado Tarija (COSAALT), Servicio Nacional de Meteorologia e Hidrologia (SENHAMI), and Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ). Overall, the USGS is developing an integrated global approach to sustainable groundwater development and technical capacity building.

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Session Classification : Parallel

Track Classification : Topic 9 - Groundwater and socio-economic development in Latin-America
Risk assessment of not achieving good chemical status of groundwater bodies in Slovakia

Monday, 23 September 2019 16:00 (60)

Directive 2000/60/EC of the European Parliament and of the Council (WFD) defines in Article 4 "environmental objectives" for surface waters, groundwater and protected areas. In order to achieve the "environmental objectives" for groundwater (GW) (Article 4.1b), the WFD requires the adoption of specific measures to prevent and limit GW pollution. The basis for many of the WFD risk references is the concept that underlies the environmental impact of human activities, especially those that threaten our ability to meet the WFD’s objectives (5 main objectives for GW).

In accordance with the WFD, Groundwater Directive (2006/118/EC) and CIS Guidance Documents no. 26 (Guidance on risk assessment and the use of conceptual models for groundwater), the risk analysis of not achieving good chemical status was developed and performed for each of the pre-quaternary and quaternary groundwater body (GWB) in the SR considering conceptual model. Risk assessment includes the following factors:

1. previous risk and chemical status assessment in the previous cycle,
2. trends in pollutant concentrations in monitoring point,
3. GW vulnerability,
4. significant point sources of pollution (environmental burdens),
5. use of plant protection products (pesticide active substances) and fertilizers on agricultural land,
6. sewer system for settlements,
7. the extent and degree of protection in safeguard zones and drinking water protected areas, including protected terrestrial ecosystems,
8. predicted climate, population and land use changes,
9. GW interaction with surface waters (aquatic ecosystems).

Based on the detailed risk assessment, the 6 quaternary GWBs and 1 pre-quaternary GWB (from total of 75 GWBs) were classified “in risk” of not achieving environmental objectives in the GWB by 2021. GW vulnerability was identified as an important risk factor. This factor is less time-changing and has little to do with human activity. From the view of anthropogenic impacts, the environmental burdens and the use of pesticides were assessed as significant factors. Less important factor was fertilization. The re-evaluation of all factors (except of factors 3 and 8) within developed risk assessment methodology is being performed for assessment of not achieving environmental objectives in the GWB by 2027. These results of the risk analysis are taken into consideration when making proposals for program of measures.

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Session Classification : Poster with refreshments

Track Classification : Topic 1 - Groundwater assessment and management
The role of groundwater in supporting eco system and cultural services in North West England

Friday, 27 September 2019 11:45 (15)

This paper describes the importance of groundwater to the coastal habitats of the sand dunes in North West England. The sand dunes support an aquifer that extends for 20km between Liverpool and Southport. They provide a range of natural habitats, sites of special scientific interest and a number of nature reserves (https://www.sefton.gov.uk/around-sefton/coast-countryside.aspx). It also supports cultural services (landscape, tourism, art) and international quality recreation facilities such as the famous Royal Birkdale Golf Club and others. Groundwater levels in the sand dunes have been monitored monthly since 1972 and at 30 minute intervals since 2010. Seasonal changes in recharge cause groundwater levels to rise and fall 0.5-1.0m between winter and summer. The long term observations suggest a gradual lowering of water levels of 0.15m over the last 45 years, despite the sea level boundary rising by 0.1m over the same period (https://www.ntslf.org/products/sea-level-trends).

The importance of groundwater in the various nature reserves is demonstrated by the emergence of fresh water ponds each winter. These areas are extremely biodiverse, supporting up to 100 plant species per square meter (Houston, 2008, Natural England, 2014) together with IUCN Red List species (www.iucnredlist.org/) such as the Natterjack Toad (Epidalea calamita).

Concerns have been raised that climatic change and human actions such as agricultural drainage in the adjacent areas may adversely affect the groundwater levels which in turn may cause breeding ponds to dry up and the loss of biodiversity (Curreli et. al., 2013). Another impact is a reduction in the natural sub irrigation of the fairways and greens of the numerous golf courses in the area. Various 1D and 2D groundwater models have been developed to explain the annual and long term changes in ground water levels (Clarke and Sanitwong, 2009, Abesser et. al., 2017). These have been tested against the 45+ years of monitoring data. Information from this modelling work is enabling conservation planners to identify areas of the dune system that will be of concern to managers. Coastal processes are creating new land that will become suitable for the creation of new nature reserves. A new approach to conservation may become necessary, where ecosystems relocate spatially and conservation management will have to become more dynamic.


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Session Classification : Parallel
Track Classification: Topic 6 - Groundwater, wetlands and natural heritage
Extending the knowledge about the Tikuna Aquifer - Western Amazon

Monday, 23 September 2019 16:00 (60)

The transboundary Amazonian Aquifer System extends over a vast territory of around 2.7x10^6 km² in the western Amazon. Its major portion is located in Brazil, although comprising areas in Peru, Ecuador and Colombia.

The Amazon Aquifer System is composed of three major hidrogeologic subunits: the outcropping Alter do Chão and Solimões aquifers, and Tikuna Aquifer, a confined extension of Alter do Chão aquifer. From these subunits, the Tikuna Aquifer was the last one to be defined. The other two subunits have historically been used as water supply sources in the Amazon plain. Tikuna Aquifer has a limited water use, both due to its location, involving the great depths and remoteness of the western Amazon region, and its quality, that is predominantly composed by brackish water, saltwater or even brines, sometimes with a high temperature, except near recharge areas or in the farthest discharging areas.

Sampling campaigns were focused on aquifer recharge and discharge areas with relatively easy access, due to high field trip costs in the region as a consequence of remoteness and lack of transport means. Study areas comprised Ecuadorian provinces of Napo and Sucumbios, Peruvian Contamana city in Ucayali province, Serra do Divisor highlands in Acre State, Brazil, and the Eastern border of the aquifer system, in Iranduba, Manacapuru, Careiro, Manaquiri and Codajás cities, in Amazonas State, Brazil. The integration of hydrochemical data, groundwater head measurements, and other geological data, such as geophysics and stratigraphic data, obtained both during field campaigns, cooperation with research groups in Brazil, Ecuador and Peru and literature review, allowed developing the Tikuna Aquifer flow conceptual model and a regional 3D mathematical flow model considering a variable density water flow, using a modified version of the finite-element CODE_BRIGHT (COupledDEformation, BRIne, Gas and Heat Transport) code, originally developed by the Geotechnical Engineering Department at Politecnical University of Cataluña, Spain.

From the field work, some new Tikuna Aquifer discharging areas have been identified. These discharging areas have peculiarities, such as the discharge of very hot water, forming cascades and high temperature rivers in the Peruvian territory. Hydrochemical facies comprise HCO₃(Cl)-Na-Ca waters with Cl-Na waters in salty water bodies. Isotopically, 14C age dating and 18O-2H results showed a well-behaved aquifer system in agreement with the conceptual model initially proposed by Rosário et al. (2016). One regional numerical flow model helped to identify the groundwater connection between Ecuadorian and Peruvian aquifer basins with the Brazilian Amazonian aquifers and its influence over the groundwater quality and flow pattern.

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Session Classification: Poster with refreshments
Track Classification: Topic 1 - Groundwater assessment and management
Use of Geographical Information System and Water Quality Index to Assess Groundwater Quality in krimat Aquifer (Essaouira; Morocco)

Thursday, 26 September 2019 17:45 (15)

Groundwater is the most important natural resource required for drinking and agricultural purposes, especially in arid and semi-arid areas. The main aim of this research is to evaluate the groundwater quality of krimat aquifer and to identify the places with the best quality for drinking based on Water Quality Index (WQI) by using Geographical Information System (GIS).

The results of physico-chemical were compared to the standard values as recommended by the World Health Organization for drinking. However, the analyzed parameters pH, NO3, Na and K are below the desirable limits of WHO and the parameters Ca, TDS, SO4, Cl, Mg and HCO3 are above the desirable limits of WHO.

The contouring methods by exploiting Arcview spatial distribution maps of almost parameters with an interpolation technique (ordinary Inverse Distance Weighted), was used to obtain the spatial distribution of groundwater quality in krimat aquifer (Essaouira Region). The spatial distribution of groundwater quality patterns in the study area shows that the TDS values decreases from north-west to south-east. The results obtained showed that the WQI values range from 45 to 327 over 62 of the water samples and therefore can be categorized into five groups: excellent water to water unsuitable for drinking. In global, 52% of groundwater sites sampled in the study area had poor water quality, while 24% were good water. Regrettably, 18% of the samples indicate very poor water quality, 5% represent water unsuitable for drinking and 1% is excellent water. The results indicate that the most water is not safe for drinking and needs further treatment.

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Session Classification : Parallel
Track Classification : Topic 5 - Tools, methods and models to study groundwater
An example of the use of GIS tools to forecast the inflow of groundwater to underground mining excavations - the use of a modified hydrogeological analogy method for copper mines in the Fore-Sudetic Monocline.

Tuesday, 24 September 2019 16:00 (60)

Authors have presented the theoretical assumptions for a modified and simplified method of forecasting the inflow of water to underground mine excavations using open-source GIS software. The proposed solution is based on the determination of the value of mine-water inflow index (qA) that represents a unit of mining excavations area. 

The proposed version of the method includes the variation of inflows to mining excavations (zonality of inflows) and depends on the volume of inflows from the time that has elapsed since the excavations were made (determination of intervals of characteristic values of inflows within the spatial zones).

The paper compares the values of the mine-water inflow index (qA) that were applied to conduct inflow forecasts to values determined on the basis of actual inflows to mining excavations. Values of mine-water inflow index applied in forecasting based on multiannual verified measurements of inflows to excavations. Data analysis and forecasting were performed for a selected area of the copper ore mine within the boundaries of the Fore-Sudetic Monocline.

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Session Classification : Poster with refreshments

Track Classification : Topic 5 - Tools, methods and models to study groundwater
Estimating of Surface and Groundwater Availability and Demand from Lower Chambo River Basin (Ecuador), as a tool for Water Management.

Monday, 23 September 2019 16:00 (60)

This work proposes a zoning method as a tool for water management and it is applied to lower Chambo River Basin, located at Chimborazo Province (Ecuador). In order to achieve this goal, it was necessary to estimate the availability of surface water as well as of groundwater in the basin. The amount of exploitable groundwater was computed using standard water balance methods and Darcy mass balance relation, estimating thus the aquifer recharge. The conceptual model for the groundwater circulation is based on physiochemical, chemical and isotopic analysis applied on samples collected from spring and wells. The potential surface water supply was estimated from a hydrological analysis using the reported flow rate of rivers in the basin, which shows consistency with the measured values of local precipitation. The water demand in the basin was estimated using the rate of urban water consummation in the two biggest cities in the basin (Riobamba and Guano), the reports of the concession agreements from the National Water Secretary (SENAGUA) and the minimum water necessary for farming the products that are grown in the basin from the FAO report (1991).

It was possible to identify three multilayer aquifers, with an origin volcano-sedimentary (Llío-Guano, Riobamba and Yaruquíes) composed by volcanic deposits from Chimborazo, Igualata, and El Altar. These aquifers are fed mainly by two mountain ranges; from the west (Chimborazo and Igualata) and from the east (El Altar). The recharge has also a secondary contribution from local precipitation. The Chambo river becomes the main discharge of the surface flow and groundwater. Hydrogeochemical and isotopic data ($^{18}$O and $^2$H) evidence the possibility of two sources for groundwater. Llío and Riobamba aquifers are composed of calcium-magnesium bicarbonate waters, from slightly acidic to neutral as well as with enriched $^{18}$O and $^{18}$H. The Yaruquíes aquifer is constituted by waters from sodium-bicarbonate to calcium-magnesium. While the springs located in Cubijíes are constituted by sulfate waters with more depleted of $^{18}$O and $^2$H values, indicating that there is influence of the volcanic activities from El Altar. From those results and from morphological and water availability characteristics, the study area was divided into eight zones. Our results show there exists an unequal relationship between management and water usage in the eight defined zones, prioritizing water usage for farming and cement industry to the detriment of urban and rural supply. In this sense, we propose a water management for the basin to short (one year), medium (five years) and long term (twenty years).

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Session Classification: Poster with refreshments

Track Classification: Topic 1 - Groundwater assessment and management
Preliminary results of the simplified VarKarst semi-distributed model applied at an overexploited karst system: the case of Torremolinos – Alhaurín de la Torre aquifer (Mijas range, Málaga - Spain)

Tuesday, 24 September 2019 16:00 (60)

Carbonate (karst) aquifers constitute an important source of drinking water for large parts of the world population. Nevertheless, the stress on groundwater resources has increased significantly in recent decades in terms due to excessive pumping and the decrease of rainfall produced by climate change at many regions. Numerical models are important tools to improve water management. In this study, the simplified version of the semi-distributed VarKarst model has been improved to simulate piezometric variations in areas where the volume of pumping affects the groundwater level and the flow behavior is not typically karstic. This new version of VarKarst has been applied at the Torremolinos – Alhaurín de la Torre carbonate aquifer (Mijas Range, Southern Spain), which is characterized by a diffuse flow behavior caused by the high degree of fracturation and the low karstification developed in the marbles. The aquifer is overexploited nowadays, and additional water resources are necessary to supply drinking water to an important touristic region of Spain. To apply the new VarKarst model at this aquifer, simulated groundwater level dynamics were compared to piezometric level records from four representative pumping wells along Torremolinos – Alhaurín de la Torre aquifer. Eight years of simultaneous record of water level variations were used in the calibration procedure. The R2 and the root mean squared error (RMSE) of simulated and observed groundwater levels ranged from 0.90 to 0.99, and 0.36 m to 22.05 m, respectively. All observed trends of piezometric levels were correctly modeled. We conclude that the optimized simplified VarKarst numerical code can provide, in a first step, realistic hydrodynamic results in carbonate aquifers affected by pumping wells and with diffused flow behavior. In the near future, this numerical model could help to enhance the water management in karstic and fissured aquifers.

Keywords: modeling, VarKarst, carbonate (karst) aquifer, pumping wells, piezometric level
Coupled climatological and hydrogeological models used for predictive managements in the Hungarian parts of the Pannonian basin, special focus on groundwater dependent ecosystems, and various developments of irrigation.

Tuesday, 24 September 2019 11:45 (15)

A dynamic modular approach was developed in order to quantitatively simulate the groundwater table and discharge under various climate conditions:

1. A toolset was developed to calculate climate zonation from climate parameter grids;
2. Recharge zones (Hydrological Response Units, HRU’s) were delineated based on geology, land-use;
3. Recharge was calculated for various climate conditions for each recharge zone using 1D analytical-empirical hydrological models;
4. Groundwater table and discharge, (exfiltration) was calculated under various climate conditions using numerical groundwater flow models;
5. Combination of 4 different climate scenarios: eg. two global climate models (CNRM-CERFACS-CNRM-CM5 and ICHEC-EC-EARTH with two radiation set: (the optimistic RCP 4.5, and the high RCP 8.5) and several production scenarios were coupled and calculated for predictive management goals.

The advantage of the above methodology is that in the Hungarian parts of the Pannonian basin:
• It provides a quantitative link between climate and hydrogeological conditions at large regional flow system under the pressures of different drinking, irrigation, thermal and other water abstractions;
• Modular structure provides flexibility and facilitates changes in input data, calculation tools and spatio-temporal resolution at various levels from scale of the local groundwater dependant ecosystems to the basin wide water balance calculations.

Recharge zones (HRU’s) were determined based on surface geology, land-use conditions. The HELP hydrological model was used for the calculation of 1D water balance for hydrological response units. The MODFLOW numerical groundwater modeling code was used for the calculation of the large scale 3D water balance and head patterns under various climate and production conditions.
Delineation of wellhead protection zones for the control of point pollution sources in the Lusaka Aquifer System, Zambia

Tuesday, 24 September 2019 12:00 (15)

The protection of groundwater resources is worldwide considered a task of high importance and imperative necessity due to their rapid deterioration and the subsequent risk of public health. A task that in its most common practical implementation is equivalent to the protection of water-supply wells through methods and techniques that result in the determination of site-specific protection areas around the individual wells. In the interior of these areas activities that might deteriorate the fresh water physical status, and particularly its chemical properties, are controlled and very often prohibited. In this study, we delineate water field protection zones for the Lusaka aquifer system. A numerical modelling process that consists of: a) the simulation of groundwater flow in the Lusaka Dolomite aquifer by applying the three-dimensional finite difference model MODFLOW and b) the delineation of protection zones for the domestic water-supply wells by applying the particle tracking post-processing package MODPATH. Regarding the flow model, a steady state model was developed and a calibration process was performed. The estimation of the hydraulic conductivity distribution was optimized using a trial-and-error technique. With regard to the particle-tracking process, two simulations were performed. The first simulation tracked from the water supply wells, while the second one tracked from point pollution sources. Finally, suggestions are given for the control and management of the identified potential point sources of pollution, especially if they are located within the protection zones of the examined water-supply wells.

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Session Classification : Parallel

Track Classification : Topic 1 - Groundwater assessment and management
Informal and formal groundwater use in peri-urban areas of Jaipur, India, and implications for its management

Jaipur, the capital of the Indian state Rajasthan, is a fast growing city in the semi-arid region of northwestern India. In its expanding peri-urban areas, a huge share of the population has to rely on an informal water supply system which is often based on groundwater sources. To understand the influence of groundwater availability on the official and the informal water supply system, and the impact of the water demand and the fast changing land use on groundwater quality and quantity, a detailed research was conducted in two study areas in the northeast of Jaipur. Interviews with the population, the official water supplier, and informal water suppliers revealed that the water supply system in the two study areas is characterized by a high diversity related to water sources, service providers, pricing, quality, and transport systems. This, together with a general lack of reliable data makes an analysis of the current system challenging. Hydrogeological studies showed that in both study areas the main aquifer, the Quaternary alluvium and the weathered and fractured parts of Proterozoic quartzite, respectively, is significantly influenced by the unsustainable and un-managed use of the groundwater resources. Declining water tables indicate groundwater over-abstraction, while elevated electrical conductivities up to 7 mS/cm point towards an influence by agricultural practices as well as long-term effects due to high evaporation rates.

It is necessary to understand the close relationship between groundwater and humans, especially in fast changing environments like peri-urban areas, to be able to develop sustainable and fair management strategies for the future. For example, the current situation is highly unfair, with the quantity and quality of domestic water supply depending on the location of the house, on the economic status of the residents and on their social position within the community. Furthermore, the land-use change from agricultural to residential can even lead to a higher water demand due to the change in societal water consumption pattern coming with a changing lifestyle.

We will present our data on the water supply system, the socio-economic realities and impacts related to it and on the hydrogeology and, based on this, examine the above mentioned challenges on data availability and reliability. Furthermore, we will discuss the possibilities and constraints to model the current water demand and supply with the software WEAP (Water Evaluation And Planning) in which we included agricultural irrigation needs, domestic and industrial demand and the simulation of groundwater recharge.

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Session Classification : Parallel
Track Classification: Topic 10 - Urban groundwater
A New Method for Pore Water Content Measurement of Low-Permeability Rocks

Tuesday, 24 September 2019 12:15 (15)

A new laboratory evaporation method (EM) of the water content measurement of the low-permeability rocks with a water content of less than 1 wt.% is developed. The EM offers a rapid, efficient, and accurate analysis (error range 0.2÷6.8 rel.% if applied to real rock samples) of the free and loosely clay-bound water.

The EM was practically implemented and tested on a representative collection of 24 whole core samples (Ø 10 cm) of source-rock Bazhenov formation (BF) with the maximum preserved natural pore water content. The BF is developed within the West Siberian Plate in the Russian Federation at depths of 2–3 km, age J3v, with a fairly stable thickness of 15–50 m. To date, a reliable determination of water saturation and content is one of the important, but unsolved problems in the development of oil assets within the BF.

Using the EM for the first time a presence of free and loosely physically bound water was quantified for the BF rocks. The residual water content, that is, free and part of physically bound water in the pore space of the rocks reducing its permeability to oil varies from 0.05 to 4.27 wt.% while the content of free water is 0–3.81 wt.%. At the same time, there was no relationship between the pore water content and depth established for the target wells. The spatial variation of residual water content takes place most likely due to the heterogeneous mineral composition of the BF rocks. The presented research has shed more light on the presence and distribution of the free and loosely clay-bound water components in the reservoir rocks of the BF. The loosely clay-bound water content measured using the developed method directly correlates to the bulk clay content. The free water content, in contrast, does not depend on the rock mineral composition. Estimated values of residual water salinity reach tens of grams per liter; the corresponding isotopic composition indicates the deep formation genesis and generally correlates with that of the deep stratal waters of the West Siberia.

The dataset of the residual water content of the BF rocks will be used for reliable estimations of hydrocarbon reserves (oil, gas, bitumen), for thermodynamic modeling of the equilibrium composition of pore water and for construction of adequate petrophysical models for well log interpretation, including the spontaneous potential, electric, dielectric, neutron, and nuclear magnetic resonance logging methods. Moreover, the obtained results on the water content of various water types form a basis to review ideas about the predominant hydrophobicity of the BF rocks.

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Session Classification : Parallel
Track Classification: Topic 5.3 - Advanced modelling tools for subsurface hydrology: from the vadose zone to deep environments
Integrated approach to understand groundwater flow hosted in the karst aquifer systems of the Apuan Alps (Tuscany, Italy)

Thursday, 26 September 2019 16:00 (60)

The karst systems may be considered among the most important and strategic aquifers, given their widespread and the general high quality of groundwater flowing through them (Ford and Williams, 2007). However, due to their complexity and special features, karst aquifers have high variability of yield in time and space, as well as, they are very vulnerable to contamination, thus making it difficult to adequately manage the water resource. Furthermore, these rocks are often subject to quarrying and associated risk of pollution mainly due to the fine slurry produced during marble cutting. For a correct management and protection of these complex contest it is necessary a detailed knowledge of the aquifer system which can be obtained through an integrated approach, including not only hydrogeological, structural, and geochemical assessment, but also the use of tools not widely used in hydrogeology, as the isotope ratios (Doveri et al., 2013).

This work shows the main results from some studies in the Apuan Alps (NW Tuscany-Italy), where the main hydrogeological units are represented by metamorphosed dolostones and limestones (Doveri et al., 2019 and reference therein). High-pressure ductile deformations and the consequent metamorphism have reduced the hydraulic conductivity of bedding surface, whereas the tectonic exhumation due to low angle extensional faults has limited the development of diffuse fracture joints. For these reasons, an important subterranean storage of water is represented by epikarst porosity and vadose seepage, whereas in the epiphreatic and phreatic zones the karst conduits have a high hydraulic conductivity but a low storage capability.

The hydrodynamic behaviour of the Apuan metamorphic aquifers is characterized by enhanced karstic behaviour, as shown by springs which have a high variability of both flow rates and geochemical characteristics, as well as a weak storage capacity for supplying the base flow. Base flows of the aquifers are likely to be more related to the release of water stored in the epikarst, rather than to the emptying of minor fractures in the saturated zone. The general variability observed over time at springs of water isotopes signatures is in agreement with this conceptual model, because it requires relatively short transit times of the groundwater flow drained by the springs.

Another aspect, which is consistent with the absence of pervasive fracturing in the saturated zone and with a well-organized groundwater flow occurring along main karst fractures and conduits, is the significant difference of isotope signatures of springs very close to each other. Overall, these features make the aquifers highly vulnerable to contamination, and particularly sensitive to climate changes.

The results indicate that a comprehensive and integrated approach that involves geo-logical, hydro-physical, hydro-chemical, and isotopic tools is strongly recommended for a managing water supplies in the complex metamorphic carbonate aquifers.

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Session Classification : Poster with refreshments

Track Classification : Topic 7 - Karst Hydrogeology
Combination of hydrogeological and geophysical techniques to characterize the origin of salinity in a porous multilayer aquifer (Estepona, southern Spain)

Combination of hydrogeological and geophysical techniques to characterize the origin of salinity in a porous multilayer aquifer (Estepona, southern Spain)

Hidralia is the company responsible for the supply of drinking water to the population of Estepona, a 65,000 inhabitant’s city located in the western Costa del Sol (Málaga province, southern Spain). Water resources come from both surface (reservoirs) and ground (aquifers) sources. One of the most strategic groundwater extraction zones corresponds to Padrón sector, where Hidralia has got two pumping wells 114 and 146 m deep, respectively. Despite the fact that the two wells are situated close by (350 m) and go through the same deposits, the quality of water is quite different. The easternmost well produces water of very good quality with values of electrical conductivity (EC) around 700-800 µS/cm, whereas the westernmost one regularly suffers from salinization problems leading to significant increases of EC values up to 4,000 µS/cm. Besides, the latter eventually becomes an artesian well -usually during or immediately after the recharge period- and the salinity of water does not remain stable along the year. In consequence, the current pumping strategy in this sector depends entirely on the easternmost well and in case it would become inoperative, there would not be any operational alternative. The objective of this contribution is to clarify the origin of the salinization and characterize the factors explaining its spatial and temporal variability, making use of a combination of hydrochemical, hydrodynamic and isotopic techniques. Methodology included monthly field campaigns for in situ EC, temperature (T), pH and oxidation-reduction potential (ORP) measurements, groundwater sampling and laboratory analyses of water samples for determination of major components concentrations and water isotopic signature (d18O-d2H). CTD-Diver devices were deployed in two monitoring points for continuous EC, T and groundwater depth recording. Vertical EC profiles in selected wells were periodically carried out. Finally, electrical resistivity tomography and induced polarization was used to characterize the freshwater-saltwater interface and provide information about the subsurface geometry of the aquifer. Results show the existence of, at least, three independent permeable layers in the study area made up of Quaternary and Pliocene sands, gravels and conglomerates. Water stored in the deepest layers shows low-to-intermediate EC values (<850 µS/cm) all throughout the year, whereas the shallower levels can become salinized because of their hydrogeological connection with seawater and extensive pumping, especially during the summer season. Changes of the piezometric pressure in the various permeable layers generate longitudinal flows inside the wells which modify the vertical distribution of EC. The different salinity of water from the two wells is attributed to the configuration of the filtering screen, in such a way that the non-salinized -easternmost- well would be disconnected from the upper levels and would only pump water from the deeper aquifer. This aspect remains to be validated through borehole video inspection.

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Session Classification: Parallel

Track Classification: Topic 1 - Groundwater assessment and management
The Pianosa Island (10.2 km²) is one of the seven islands of the Tuscan Archipelago (Italy), known for its flat morphological structure. It is formed of Neogenic-Quaternary sedimentary rocks, mainly represented by calcarenite, and underlying marl and clayey marl. Despite its small extension and relatively low rainfall amount (500 mm/year, approximately), the Pianosa Island include an interesting aquifer characterized by significant groundwater resources that at present is little exploited.

The main goal of this work was the development of a groundwater flow numerical model based on a conceptual model obtained by a multi-tool and integrated approach. In particular, stratigraphic and geophysical data were elaborated to define the geometry of the aquifer system; piezometric surveys (12 campaigns from 2015 to 2018) and hydraulic tests were performed for the hydrodynamic and hydraulic characterization; and, geochemical data (physical-chemical parameters, chemical compounds concentrations and isotopic ratio) were produced on groundwater and rainfall samples (respectively collected seasonally from wells and monthly from a rain gauge) for characterizing the water inputs and components involved into the aquifer, including sea water. Recently, a specific lysimeter was moreover installed to quantify and characterize in geochemical terms the effective infiltration water.

All data processing allowed to obtain a reliable conceptual model and identify some processes that affect groundwater, as the marine intrusion. It was also possible to estimate the main input and output components of the aquifer.

Based on the conceptual model, a steady-state flow model was developed by MODFLOW code and Visual MODFLOW as graphical user interface. The implementation step involved the spatial discretization of the domain, the attribution of hydraulic parameters to each cell and the assignation of initial head and boundary conditions. The model implemented was then calibrated with measured data using a manual “trial and error” approach. On the whole, the groundwater model confirms the hydogeological conceptual model and identifies some knowledge gaps which need further investigation.

The calibrated groundwater flow model let us also to simulate forecasting scenarios with different rate of groundwater exploitation and different value of effective infiltration. The results indicate that the variable that mostly intensifies the marine intrusion phenomenon is a reduction of the effective infiltration, thus confirming that the aquifer system of the Pianosa Island is strongly sensitive to rainfall regime and climate change.
Council of Italy, Pisa, Italy)

Session Classification: Poster with refreshments

Track Classification: Topic 5 - Tools, methods and models to study groundwater
Uranium and arsenic in groundwater on Fogo Island, Newfoundland, Canada

Tuesday, 24 September 2019 16:00 (60)

Fogo is an island with a surface of around 237 km², located in the northeast of central Newfoundland. Around 2,400 people live on the island. The geology mainly consists of granites with an age of around 410 million years. Some dolerite intrusions as well as ash-flow tuffs appear locally.

It is known that a statistically high number of residents on Fogo Island suffer from cancer (personal communication with the local hospital), although the cause for high cancer rates is not confirmed. However, it is assumed that consumption of untreated water might be the cause, if high uranium (U) and/or arsenic (As) levels are present. This assumption justifies the investigations presented here.

A water sampling campaign was conducted in August/September 2018 to assess concentrations in different water supply wells on Fogo. Analysis revealed that 6 out of 20 groundwater samples in Central Fogo and Joe Batt’s Arm show exceedances of the maximum admissible concentration (MAC = 10 ppb) and 3 out of them exceeded 20 ppb. Additionally, the MAC for uranium (20 ppb) is exceeded in 9 out of 20 groundwater samples. Except one sample, all wells with high arsenic concentrations show concurrently elevated uranium concentrations. No arsenic or uranium exceedances, however, are found in any of the surface water samples from brooks and springs or in Joe Batt’s Arm in the north. In Central Fogo, As is elevated east of Highway No 333, while samples in the west do not show values exceeding MAC, potentially indicating different groundwater flow paths, here.

Curie (2003) as well as Sandemann and Malpas (1993) analyzed uranium concentrations in 53 and 9 rock samples (mainly granites), respectively, in different areas on Fogo Island. In contrast to concentrations found in groundwater, these measurements reach maximum values of 9 ppb in Shoal Bay granite and 7 ppb in ash-flow tuffs, only. Different processes are known to enhance accumulation of radionuclides in groundwater (physical recoil, chemical weathering and milieu changes, e.g. low redox potential fronts). Long groundwater residence times, and thus contact times with the bedrock, are crucial for these processes.

The wide range of As and U concentrations over a short distance of around 2 km in Central Fogo suggests that different groundwater flow paths exist within this limited area. Despite no MAC exceedances were found in treated water samples, e.g., by reverse osmosis, it cannot be concluded that such water samples are always free from As or U. Monitoring of U and As on Fogo island in drinking water is strongly recommended in future.

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Session Classification : Poster with refreshments
Track Classification: Topic 8 - Groundwater quality and pollution processes
Application of SWAT and MODFLOW models to simulate groundwater flow in a coastal multi-aquifer system in Puck region (northern Poland)

There is an increasing need to develop modeling tools capable of simulating water flow and pollutant transport across different environmental compartments, such as inland surface waters, groundwater and seawater. Such an integrated modeling approach is proposed in the framework of the project "Modelling of the impact of the agricultural holdings and land-use structure on the quality of inland and coastal waters of the Baltic Sea set up on the example of the Municipality of Puck region – Integrated info-prediction Web Service WaterPUCK", funded by National Centre for Research and Development (NCBR), Poland, (BIOSTRATEG3/343927/3/NCBR/2017). The project focuses on water flow and transport of nutrients and pesticides in Puck Bay (part of Baltic Sea, separated from open sea by Hel Peninsula), as well as in the adjacent coastal watershed, which contributes surface and subsurface discharge to the sea.

The considered land area is about 300 km². The geology is typical for young glacial areas, with multiple sand aquifers separated by weakly permeable glacial tills. Groundwater flow is directed from moraine uplands towards the sea, and focuses in deeply cut ice marginal valleys, where the sand aquifers are partly confined by layers of peat. Most of the area is used for agriculture and forestry.

We applied SWAT model to represent surface and soil hydrological processes and MODFLOW to represent groundwater flow. The SWAT model includes 17 subbasins and 353 hydrological response units (HRU). Due to complex geological structure, the MODFLOW model has relatively detailed discretization, with 6 layers and more than 700 000 cells. The preliminary calibration of the groundwater model was done for steady state conditions. The values of recharge were taken as average results from SWAT simulations for each HRU, corresponding to the period 2000-2015.

The recharge rates calculated by SWAT showed a reasonable agreement with the values estimated by a simplified method, based on multiplying the rate of precipitation by correction factors representing influence of soil type, land use, slope of the ground surface and depth to groundwater table. The groundwater model allowed to estimate the rate of submarine groundwater discharge to Puck Bay. As the next step, the SWAT and MODFLOW models will be coupled using the recently developed SWAT-MODFLOW-RT3D computer code and applied to transient simulations of surface and subsurface flow and contaminant transport.

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Session Classification: Poster with refreshments
Track Classification: Topic 5 - Tools, methods and models to study groundwater
Groundwater response to meteo-climate variation: example from the foothill aquifer system of the Piedmont Alpine zone (NW Italy)

Monday, 23 September 2019 16:00 (60)

Many foothill zones in Italy contain aquifer systems of strategic interest for water supplying, especially for drinking purposes (Doveri et al., 2016). The hydrogeological features in these environments generally promote the infiltration of both local rainfall and seepage from stream water originating in mountain catchments. On the other hand, because of their linkage with mountain areas, these systems are characterized by significant sensitivity towards the meteo-climatic variations and changes. To cope with climate change, a high level of knowledge of this type of aquifer should be reached in order to address the water management issues. This work focus on the aquifer system extending in the foothill plain located in the Piedmont region (NW Italy), between the Western Alps and the Torino Hill (Piana et al., 2017). Taking into account previous studies (De Luca et al., 2014 and references therein) and datasets from monitoring activities institutionally performed by the Environmental Protection Agency of Piedmont Region (ARPA Piemonte), the study examined the geological, hydrogeological and hydraulic-hydrodynamic features of the aquifer, as well as the chemistry of groundwater. This comprehensive approach steered the definition of the aquifer system conceptual model as well as the evolution of groundwater quantity and the chemical quality of groundwater. The statistical analysis performed on datasets highlighted some trends over the lasts two decades, both for groundwater quantity and quality. In particular, a significant sensitivity to meteo-climate conditions was pointed out by high confidence trends of piezometric level decrease occurred over both the periods 2004-2008 and 2010-2017, because of the respective rainfall decrease patterns. The rainy year 2009, which interposed itself between the two relatively dry periods, promoted sharp increases in terms of piezometric levels and concentrations of some chemical compounds in groundwater, thus pointing out as the hydrologic extremes can lead to the accumulation of nutrients and salinity in the unsaturated zone of the aquifer and their successive concentrate release in groundwater.

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References

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Session Classification : Poster with refreshments

Track Classification : Topic 2 - Groundwater and climate change
SUSTAINABLE GROUNDWATER MANAGEMENT IN THE CONDADO AREA - QUITO, ECUADOR

A hydrogeological study was conducted in the Condado neighborhood in Quito Ecuador, in order to provide drinking water in this area. The aquifer is confined, multilayer type with complex geometry and boundary conditions, several pumping tests were carried out to obtain the hydraulic aquifer parameters, and a numerical model was implemented simulating various pumping scenarios, including existing and future wells. The aquifer recharge comes mainly from the mountainous zone, in the urban zone is mainly artesian, and an average recharge of 380 L/s was obtained through model calibration. The mean aquifer thickness is 200 m, with approximately 947 million m3 of water in storage. The mean aquifer sustainable yield obtained for the next 25 years is 480 L/s was obtained, including 20% of water from storage.

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Session Classification : Parallel
Track Classification : Topic 1 - Groundwater assessment and management
New evidence of recent recharge of the Continental Intercalaire transboundary aquifer, north-west of Algerian Sahara, using hydrochemical and isotopic technics

The northern Sahara contains vast transboundary aquifer system, including the Continental Intercalaire aquifer (CI) which is the main water reserve for those hyperarid regions. It is shared between Algeria, Libya and Tunisia.

The piezometric map shows that the main groundwater flow comes from the “Occidental basin” considered as the principal recharge area of CI aquifer. However, it is the less studied part of all the aquifer.

The hydrogeochemical data are really scare in the occidental basin even that some recent researches have demonstrated, using mathematical modelling of fluxes and satellite technics, that CI aquifer should receive more important recent recharge below dunes of occidental basin, where CI is unconfined, than it was expected in older studies.

Our study has identified processes that control hydrochemistry of CI groundwater and discussed information got from stable and radioactive isotopes in the northern part of the occidental basin (Ghardaia region and neighbouring cities).

We concluded that CI groundwater, there, behaves as two distinct groups, according to geographical localisation (north: Ghardaia region, and south: El Goléa region); the dissimilarities are much contrasted. Samples situated between 31.55° and 31.57°N of latitude represent a transition within the occidental basin. This finding corroborates previous observations from regional piezometry suggesting groundwater divide situated in this zone.

In north, samples are highly mineralized, they belong to SO4-Cl-Na type; in south, they are poorly mineralized and predominantly belong to HCO3-Ca type. Actually, in north, CI aquifer is clay and gypsum-enriched, however, toward south it is almost totally sandy.

Stable isotope data (δ18O and δ2H) shows that all samples are much depleted in both δ18O and δ2H comparing to the actual rainfall isotopic signature, but in south CI groundwater are more evaporated than in north. Such pattern suggests that CI groundwater has infiltrated under climate regime cooler than the current one. Moreover, southern samples seem to indicate a mixture with recent evaporated water.

36Cl cosmogenic isotope results show that 36Cl/Cl ratio in south region is higher than 116×10^-15 at/at considered in literature as “the initial ratio”. This finding gives two indications:
• First, it confirms that CI groundwater in south is younger than it was expected previously.
• Secondly, the initial 36Cl/Cl ratio supposed in literature is less than its real value.

Later, we will use 14C and noble gases to reinforce our results and calibrate an initial 36Cl/Cl ratio more accurate with real data.

As perspective of this work, we suggest to implement a monitoring network of CI in the occidental basin in the aim of more sustainable management of this valuable resource.

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Session Classification :  Parallel

Track Classification :  Topic 1 - Groundwater assessment and management
Empirical model as tool for a correct management of groundwater: an experience on a carbonate aquifer in Tuscany (Italy)

Monday, 23 September 2019 16:00 (60)

Most of the available freshwaters on Earth are stored in the underground, consequently groundwater represents the main resource in term of water supply. The exploitation of groundwater bodies will increase to face the significant increasing of the global water demand, which has been predicted as a consequence of the future economic expansion, population growth, and urbanization (Rosegrant et al., 2002). Furthermore, the reliance on this resource is continuously growing given the key role that groundwater plays for mitigating the climate change/variability. The estimation of the entity of these effects is mandatory for a reliable management of this crucial resource, which must be protected by suitable actions in order to guarantee safe water supplying for the next generations (Doveri et al., 2016). This work is focused on the water resources destined to the drinkable water distribution, by studying possible empirical relationship between meteorological parameter and groundwater quantity indices. This activity is in the wider context of a research for the development of support tools for the management of the resources under specific climate scenarios. Furthermore, for what regards carbonate aquifer, the impact of climate change can be very significant, given the high sensitivity caused by their karst features. In this work, flowrate of the Cartaro spring (draining a karst aquifer of the Apuan Alps, northwestern Tuscany) and meteorological timeseries (both historical and synthetic scenarios) in the relevant hydrogeological basin were used. Flowrate measurement were provided by the Tuscan Water Authority (AIT) and GALA ApA (Integrated Water Service), while synthetic meteorological scenarios were provided by Consorzio LaMMA. This work describes the data-driven approach experimented with the collected time series, essentially based on multi-variate analysis techniques and on a simplified machine learning scheme based on neural networks. In fact, a preliminary test of a data-driven approach based on Multi Layer Perceptron Neural Networks (MLP-NN) is described here. Dedicated techniques for data pre-processing, training and validation have been experimented. In particular, a strong hypothesis of linearity and time-invariance of the system under observation was done, and MLP-NNs were essentially used as non-linear approximators. A further activity regarded the assessment of a performance metric for the evaluation of multiple MLP-NNs with respect to independent test sets, based on either historical or synthetic data. Results are shown in terms of predicted flowrates in a given time window (up to 90 days in our case study), and are organized according to different scenarios of total rainfall quantity.

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**Session Classification:** Poster with refreshments

**Track Classification:** Topic 1 - Groundwater assessment and management
REMOTE SENSING FOR SUBSIDENCE ANALYSIS DUE TO GROUNDWATER USE IN THE BOGOTA PLAIN, COLOMBIA

Friday, 27 September 2019 12:15 (15)

Groundwater depletion is a subject of high concern that is not only being caused by pumping, but also due to climate change, population growth and contamination of water sources. In this paper, we present the simulated subsidence in the Funza-Madrid sector by pumping, draining in Bogota city, and also the subsidence calculated with the use of remote sensors (Sentinel and Grace) for a period between the beginning of 2015 and mid-2016. With remote sensing, a total subsidence of 2 cm (0.12 cm / month) was calculated. This is associated with a total drawdown of 34 m (1.62 m / month) where the most relevant one occurred between September 2015 and January 2016 (2 cm / month). A correlation between precipitation series and the drawdowns was found, where the low precipitation values triggered significant water levels decreasing. The highest values of subsidence and drawdowns occurred in the southwestern zone of the plain (Sibate, Funza, Mosquera, Soacha, among other localities) which can be attributed to the strong El Niño weather event that occurred between 2015 and 2016. It is concluded that the estimated subsidence is due to the levels decreasing as a result of groundwater use in the Bogota plain.

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Session Classification : Parallel

Track Classification : Topic 9 - Groundwater and socio-economic development in Latin-America
Study of pollutants propagation in mining areas for groundwater safeguarding: the example of thallium contamination threatening some drinking springs in the Apuan Alps (Italy)

Tuesday, 24 September 2019 16:00 (60)

Drinking water is a very important topic for people and society. Groundwater usually represents the most important source of drinking water in terms of quantity, safety and reliability. In mountain areas important sources of water supply are hosted in carbonate aquifers, in relation to groundwater quality and quantity. However, high effective infiltration coefficients and low groundwater residence time induce high flow variability and groundwater vulnerability, implying a high risk of contamination. This is stronger in mining areas.

The Baccatoio Torrent basin (NW Tuscany, Italy) includes all these features: different carbonate aquifer systems which locally interfere with abandoned mining areas, characterized also by acid mine drainages. This area includes several orebodies made of pyrite, baryte, and iron oxide. Pyrite ores contain high levels of PTE, including exceptional Tl concentration, among the most toxic elements to humans (Environmental regulations of the European Community adopted by Italy pose a maximum concentration level for Tl in groundwater of 2 μg/L; however, at present drinkable water must not abide any concentration threshold for Tl and it is not routinely monitored).

This study analyses some springs (named Molini S. Anna-VSMSA, Moresco Alta-VSMOA, Moresco Sondaggio-VSMOS and Moresco Galleria-VSMOG) fed by carbonate aquifer systems. A multidisciplinary integrated approach, based on geological surveys, flow rate and level measurements, sampling, chemical and isotopic analyses, allows to characterize the springs and to understand preliminarily the groundwater flow and the origin of the contamination.

The first one (VSMSA), located at higher altitude and fed by a metamorphic dolostone-marble aquifer, resulted contaminated in Tl (5-30 μg/l) and removed from the local drinking water network. Tl-contamination results from the binary mixing of two sources: an uncontaminated component constituted by Ca-HCO3-type water that mixes with waters from a contaminated body formed by the interaction of acid drainages generated by the weathering of Tl-hosting mineral phases with dolostone rocks.

The second group of springs are located at lower altitude and are close to each other, but only VSMOG feeds the aqueduct, because the others occasionally contain PTE including Tl (up to 2.5 μg/l). Also the Moresco springs show a dominant Ca-HCO3 composition, confirming the presence of a carbonate aquifer system. Flow rates, hydraulic levels and EC hydrographs highlight two different groundwater flow systems: the first one, shallower, feeding VSMOA and VSMOS; the second one, deeper, feeding VSMOG and showing higher SO4 concentration, temperature and EC, as well as approximately constant isotopic composition, confirming the presence of a deeper circuit. Data point out a likely connection between Baccatoio Torrent and VSMOA and VSMOS springs, inducing contamination.

These examples highlight the importance of the knowledge of the aquifer systems and of the processes involved in groundwater circulation in order to use natural water resources as drinkable water.
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Session Classification : Poster with refreshments

Track Classification : Topic 8 - Groundwater quality and pollution processes
Density dependent flow, multispecies transport and geochemical modeling and applications: The code GEODENS

GEODENS is a FORTRAN code for modeling partly or fully saturated density dependent flow and multispecies reactive solute transport in porous media under both local chemical equilibrium and kinetic conditions. It can handle geochemical reactions such as mineral dissolution-precipitation processes. Its main purpose is to represent the physicochemical processes in the subsurface system. The code considers flow, transport and geochemical reactions in porous media. GEODENS comprises two modules, (i) the density dependent flow and multispecies transport module and (ii) the geochemical module. The mathematical formulation of the first module leads to a nonlinear and strongly coupled equations. In order to solve such equations, a finite element method has been developed with a consistent numerical scheme of gravity terms to calculate Darcy velocities (Voss, C. I., 1984. SUTRA: a finite element simulation model for saturated–unsaturated fluid density dependent groundwater flow with energy transport of chemically-reactive simple-species solute transport. US Geological Survey Water-Resources Investigations 84-4369). The second module focuses on salts and brine geochemistry using the Pitzer model (Pitzer, K. S., Peiper, J. C., Busey, R. H., 1984. Thermodynamic properties of aqueous sodium chloride solutions. J. Phys. Chem. Ref. Data 13, 1-102). This geochemical module allows the calculation of ions and solvent activities as well as the density of the solution. Reactions of salts including dissolution-precipitation processes are controlled by diffusion and are represented by a first order kinetic law. The hydrogeochemical model presented in this paper integrates the two modules described above. The code iteratively calculates the quantities of the different salts that may precipitate or dissolve in a solution when the system is displaced from its equilibrium. This may occur due to evaporation or mixing with a different solution. The system’s hydrodynamic parameters may also change due to mineral dissolution-precipitation reactions. Cases of study presented here are related to seawater intrusion in carbonate coastal aquifers and to Sebkha genesis with salts deposit after seawater evaporation through geological time.

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Session Classification: Parallel

Track Classification: Topic 5.4 - Innovative approaches for understanding groundwater flow systems
Thermal Impact and Performance of High-Temperature ATES (HT-ATES) systems: a strong dependence on hydrogeological and storage conditions

Monday, 23 September 2019 18:00 (15)

Particularly in urban areas, heating and cooling is responsible for a large fraction of total energy demand. Due to the seasonal and diurnal variation in heat demand and for example that of solar heat supply, the storage of heat is critical for the development of sustainable heating.

Aquifer thermal energy storage (ATES) systems allow the storage of heat cost-efficiently and at a scale that is sufficiently large to allow seasonal heat storage from office buildings to regional district heating networks (DHN). Critical for the performance of ATES systems is the heat recovery efficiency. While for low-temperature (LT, <25°C) ATES systems, recovery efficiency mainly depends on conduction losses from and displacement of the stored volume, at higher storage temperatures density differences between the stored hot water and the lower native groundwater temperatures (e.g. ~10°C in NL), result in losses by buoyancy driven flow. Particularly for HT-ATES systems, also the effects of heat loss on the thermal, chemical and microbial quality of the surrounding groundwater and that in over- and underlying aquifers still need to be understood.

We therefore focused in this study, on the controlling factors for the heat recovery efficiency and thermal impact through integrated density-dependent, heat transport and groundwater flow modelling of ATES systems for a wide range of representative storage (e.g. T:15–90°C, storage volume: 10,000–1 Mm³) and hydrogeological conditions. Results showed that for storage temperatures up to 30°C, under all conditions tested, conduction losses were dominant in controlling recovery efficiencies (55–85%), as evidenced by its observed strong linear correlation with the thermal area over volume ratio (A/V) with an optimum ~2 for the aquifer thickness over thermal radius ratio (L/Rth) for a particular storage volume. For storage temperatures of 45 and up, the negative impact of density driven flow was significant and became the dominant control for lowering of the observed recovery efficiencies (18–75%) at 90°C. From 45 to 90°C, the recovery efficiency was progressively more negatively and non-linearly correlated with L/Rth, with the highest recovery efficiencies at the lowest tested L/Rth (0.1). In addition to storage temperature and volume, the thermal impact on the simulated overlying aquifer depended strongly on the thickness of the confining aquitard. For the heating of the aquifer overlying and surrounding the HT-ATES system, an analytical 1-D conduction and 2-D radial conduction expression was found to give a good first approximation, respectively, but deviated at higher temperatures due to the occurrence of buoyancy flow at higher storage temperatures.

Overall, it is shown that both the performance and impact of a particular HT-ATES system strongly depends on a range of site-specific storage and hydrogeological conditions. These need to be considered carefully for system optimization and assessment of business cases and potential thermal environmental impact.

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Session Classification : Parallel
Track Classification: Topic 10 - Urban groundwater
Impact of low flow conditions on microbial signature and natural attenuation in a karst aquifer

Thursday, 26 September 2019 12:00 (15)

While drought conditions may create severe problems in terms of karst groundwater scarcity, related low flow provides prolonged residences times and enhanced natural attenuation capacity. This is particularly relevant with respect to microbial water composition and related fecal pollution. Stable base flow following long-standing drought, such as encountered in Europe during summer and fall 2018, represents the unique possibility to study in detail the related processes at work and to characterize the impact of residence time on microbial signature and water quality.

Investigations performed at the Milandre test site in the Swiss Jura Mountains document the gradual change of hydrodynamics in the course of the drought event, including the discrimination of discrete conduit flow paths becoming more apparent with decreasing discharge. Furthermore, the extreme low flow resulted in residence times that were doubled with respect to normal base flow. During this period, total cell count and fecal indicator bacteria reached lowest background values, only interrupted by sporadic pollution input linked to local rain events and reaching the active conduit through preferential flow paths despite a significant water deficit in the vadose zone.

These variations in flow and pollution dynamics, in turn, allowed for identifying the different water components and bacterial signatures. Spatial and temporal monitoring was conducted for natural conditions and complemented by manure tracing experiments during base flow. Results evidenced microbial signature being residence time dependent, with total cell count (including live/dead and LNA/HNA ratios) correlating with discharge and flow velocity. These parameters can then be used as indicators for the different flow components observed in the karst system. In the same manner, pollution events could be characterized, and reproduced by the tracing approach.

Finally, extended residence times during low flow conditions also provide the basis for better assessing natural attenuation of both degradable solutes and fecal bacteria. In this context, repeated injection of selected bacterial and dye tracers in contrasting hydrological conditions allowed determining attenuation rates and effective degradation with time. Bacterial attenuation could also be deduced from the bacterial signature, for instance the ratio of more and less persistent strains. Nonetheless, the characterization and quantification of those processes demands further research, particularly for lasting low flow conditions as observed in 2018 and to be expected more frequently in the future.

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Session Classification: Parallel

Track Classification: Topic 7 - Karst Hydrogeology
Groundwater potential of the Vichada asteroid impact structure, Colombia

Thursday, 26 September 2019 16:00 (60)

Many of the major asteroid impact structures around the world host minerals that are currently mined or have the potential to become important economic resources in the future. Even structures absent of any type of mineralization have potential as large reservoirs of surface and groundwater, interesting from the perspectives of water supply, the establishment of tourist attractions, recreational and educational. The Vichada structure is a possible asteroid impact structure located in the municipality of Cumaribo, Vichada Department, Colombia. Its structural model has been evaluated from the interpretation of satellite, airborne and ground gravimetric and magnetic anomalies. Geophysical evidence suggests the presence of a circular sedimentary basin of approximately 50 km in diameter and variable thickness between 100m to 1000m, which has been filled by sedimentary material during the Cenozoic. The geological characteristics of the structure and the high precipitation in the area of its location pose this structure as an unconventional sedimentary basin of hydrogeological interest. The hypothesis that the sedimentary basin contains an abundant amount of groundwater from an economic and social approach, makes it necessary to carry out research studies that provide the necessary technical inputs to estimate its hydrogeological potential. Therefore, this study proposes, through the integration of geophysical, geological, meteorological and hydrogeological information, to evaluate the presence of aquifer levels associated with the Vichada structure, which allow the protection, exploitation, exploitation and management of the groundwater resources in order to promote the development of the Colombian eastern plain’s region.

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Session Classification : Poster with refreshments

Track Classification : Topic 9 - Groundwater and socio-economic development in Latin-America
In Tunisia, water resources are already limited in space and time. Their sustainable management is a national priority for ensuring water security and development of the country. The Medjerda river basin is the largest watershed in Tunisia, where groundwater resources are used in conjunction with surface water. While local surface water resources are relatively well managed, groundwater resources are more hidden and difficult to conceptualize; additionally, they have the gap of groundwater data. Hydrogeological mapping of groundwater resources is one of the main tools for the controlled development of groundwater resources. Remotely sensed surface indicators of groundwater provide useful data where practical classical alternatives are not available. Integrated Remote Sensing (RS) and Geographic Information System (GIS) are widely used in groundwater mapping. Locating potential groundwater targets is becoming more convenient, cost-effective than invasive methods and efficient with the advent of number of satellite imagery. The nature of Remote Sensing-based groundwater exploration is to delineate all possible features connected with localization of groundwater. The main goal of this study is to investigate the machine learning models for Groundwater Potential Mapping (GPM) using GIS and RS at the Medjerda river basin.

This study includes the analysis of the spatial relationships between Transmissivity and various conditioning factors such as elevation, slope, curvature, river, lineament, geology, soil, rainfall, and land use. Eighteen groundwater-related factors were collected and extracted from topographic data, geological data, satellite imagery, and published maps. About 60 groundwater data of transmissivity were randomly split into a training dataset 70 % for training the model and the remaining 30 % was used for validation purpose.

Subsequently, GPM was produced using weights-of-evidence with logistic regression and functional tree models, classified as very high, high, moderate, low, and very low zones. Finally, the Receiver Operating Characteristic (ROC) curves for all the groundwater potential models were constructed and the areas under the curves (AUC) were computed. These results of GPM can be helpful for future planning in groundwater resource management and land use planning.

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**Session Classification :** Parallel

**Track Classification :** Topic 5 - Tools, methods and models to study groundwater
Articulating NUA and Strategic (health-Environmental) Assessment (SEA) in Mexico to improve groundwater management, communicate risks of severe GW lowering, and bettering governance

Sustainable management of groundwater as a reliable water source is proving to be a relevant challenge for Mexican urban areas. For large cities located over 1000 meters above mean sea level, groundwater is key in managing the water buffer for climate change adaptation and preparedness for drought.

While Metropolitan Areas in highlands have registered accelerated population and city sprawling due to poor land-use planning and weak local water agencies; illegal urban groundwater markets and hundreds agroindustry wells have intensified the vulnerability of the groundwater systems to depletion and geogenic pollution, endangering the main source of drinking water, the potential water buffer for climate change and the commitments to UN Sustainable Development Goal 6 (SDG6).

Characterizing groundwater extraction and investing in monitoring its quality and quantity with best hydrogeology practices and science can help understand and reduce groundwater vulnerability to depletion, superficial and geogenic pollution. However, to reduce legally constructed water scarcity, to protect groundwater from pollution and over exploitation, we propose strengthened and capable institutions within the framework of the UN New Urban Agenda (NUA); the integration of groundwater and decision-making through risks and impact assessment 2.0 (including decisions on land-use change and management), as well as fostering groundwater education/communication, both in formal and informal settings.

Case studies discuss if investing in capacity building and participation in general can nudge decision makers to improve implementation of NUA, groundwater impact assessments, adaptive management and monitoring; which are critical for major cities in highlands. In Mexico, the strategic environmental assessment (SEA) of a land-use plan of a conflictive area prompted a series of groundwater science and management workshops. More than 100 stakeholders from subnational and local governments, private consultancies, non-governmental organizations, and universities participated in these customized workshops. These helped challenge preconceived notions and incomplete knowledge of groundwater systems and their management challenges, for improving local solutions and the integration of water management and urban planning.

Through an urban SEA -in the context of local implementation of NUA- groundwater would be integrated into decision-making as a priority environmental issue, to address the technical, legal and institutional shortcomings of groundwater management in one of Mexico’s largest cities.

The ongoing capacity building on risk-impact assessments at local campi, collaboration with UN Habitat, international organizations, enriched NGOs’ and citizen participation; all contributed to trigger a local will to assess and improve the regional groundwater decision analysis, regulations and water impact assessment system’s structure and performance from a best practice perspective.

This presentation discusses if implementation of NUA, SDG6, investing in capacity building and participation in general, can nudge governments to do the next step and introduce new groundwater agencies, innovative cumulative impacts and risk assessments regulations.

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**Session Classification:** Poster with refreshments

**Track Classification:** Topic 10 - Urban groundwater
The current state of water resources in Chile is in such a fragile situation that 76% of the surface of the country is affected by drought, desertification and degraded soil (Emanuelli et al., 2016), and 110 aquifers are currently with a committed demand higher than its recharge (Ministerio del Interior y Seguridad Pública, 2015). Accordingly, in 2015 Chile was among the 10 countries with the highest spending associated with natural disasters (Kreft et al., 2017), with the water deficit leading to more funds, with a total of $32,947 million chilean pesos (USD 48.5 million).

A particular characteristic of the country consists in the high climatic diversity generated by the variable geomorphology along the Chilean territory. On the one hand, northern Chile is characterized by an arid climate with a very low water availability (800 m³/capita/year; World Bank, 2011). On the other hand, southern Chile has high values of water availability (10,000 m³/capita/year; World Bank, 2011). This great difference is even more abrupt when these values are compared to world average (6,600 m³/capita/year; World Bank, 2011), visualizing both critical scenarios: a large extension with a serious scarcity of water and another with an abundant water reserve that must be protected facing the water global crisis.

In this context, within the different consumptive uses of water in Chile, agriculture concentrates the 73%, domestic use 6%, mining 9% and industry 12% (Ayala, 2010). Regarding only groundwater resources, the most important use continues to be agriculture with 49%, 35% for domestic use and 16% for industry (Salazar, 2003). This distribution, together with Chilean legislation that is oriented to industrial development without hydrogeologic and environmental perspectives (rights of private use of water with abusive clauses), accentuates the water crisis in the country.

Considering the current state of the water resources in Chile, new generations of geoscientists must generate more dissemination, social debate and influence in public policies from a geological and innovating point of view, supporting with more information and updating research, with the main objective of protecting the hydrological resources regarding the whole water system, not only surface but also groundwater, and treating it as a non-renewable resource (Arumí y Oyarzún, 2006) in critical conditions, not as a mercantile resource.

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Session Classification: Poster with refreshments

Track Classification: Topic 9 - Groundwater and socio-economic development in Latin-America
Investigating geological controls on hydraulic conductivity in a karst-influenced, Paleozoic carbonate groundwater system, southern Ontario, Canada

A large set of hydraulic conductivity values has been integrated with the detailed sequence stratigraphic framework of a Paleozoic carbonate bedrock groundwater system to assess the relative influence of various geologic features on hydraulic conductivity. The geological features investigated comprise proximity to buried bedrock valleys, carbonate rock texture and sequence stratigraphic breaks. Results demonstrate that high hydraulic conductivity values do not correlate with a single geological feature but are associated with those features that have been karst-enhanced. Predicting the spatial distribution of hydraulic conductivity in carbonate rocks requires a regional understanding of the geological history with a conceptualization of where and when waters have interacted with the rocks to dissolve and enhance porosity through geologic time. This investigation focuses on a region in southern Ontario, Canada, and concludes with a map identifying the area with the greatest probability of encountering high hydraulic conductivities. While the map supports the selection of groundwater resource exploration targets for a local municipality, this investigation offers factors that should be considered when exploring for bedrock groundwater resources or characterizing contaminant transport pathways in complex karst-influenced, carbonate bedrock groundwater systems.

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Session Classification : Poster with refreshments

Track Classification : Topic 7 - Karst Hydrogeology
Groundwater as an opportunity of environmental and socio-economic sustainability: experiences of study in Latin-America countries from the AGUA FUTURA project

Thursday, 26 September 2019 16:00 (60)

As a whole, the Latin America is endowed with important water resources, which cover about 35% of renewable water resources worldwide (Mekonnen et al., 2015). However, the heterogeneous distribution of the resource determines important differences among regions, mainly in relation to the local meteo-climate conditions (Buytaert et al., 2011). Therefore, there are problems of water shortage in some territories, to which frequent pollution phenomena overlap, thus furthermore decreasing the effective water availability. These issues, together with the variability of hydrologic regimes that also the Latin-America is experiencing, make more and more difficult the water supply through the superficial water bodies, thus threatening most socio-economic and environmental contexts that at present mainly rely on this source. Consequently, the groundwater resource assumes a key role and represents an opportunity for a sustainable development in these regions.

In this framework, the AGUA FUTURA project, which is supported by the “Agenzia Italia per la Cooperazione allo Sviluppo” and carried out through a collaboration among institutions of research (CNR, UNI-FI, UNIROMA-Sapienza, INGV, USAC-Guatemala, UES-EI Salvador) and ONGs (ISCOS, ACRA), is addressing the problems of water scarcity and water quality in the Guatemala and El Salvador countries, by means of specific studies aimed at promoting the knowledge of the groundwater resource and its capability to support the local communities.

In particular, hydrogeological and geochemical surveys (water chemistry and water isotopes) are performed in main aquifer systems for verifying the effective potentiality of the groundwater resources and their possible problems of contamination from polluted streamwater or, more in general, from human activities. At the same time, a continue activity of communication and dialogue with the local communities is performed in order to promote the social awareness and sensitivity concerning the opportunity deriving from groundwater.

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**Session Classification**: Poster with refreshments

**Track Classification**: Topic 9 - Groundwater and socio-economic development in Latin-America
Hydrogeochemical study of epiperidotitic springs of the ultramafic outcrop of Ronda peridotites (South of Spain)

Tuesday, 24 September 2019 16:00 (60)

At the Malaga province (South of Spain) it is found the largest outcrop of peridotites (Lerzholites) on Earth. They are divided into three large Sierras: Sierra Bermeja, Sierra Alpujata and Sierra de Aguas. Although it is not considered an aquifer system due to its hydraulic behavior, there are hundreds of springs that drain the infiltration of rain and, to a lesser extent, snow. Some of these springs are considered hyperalkaline because they reach pH above 10 and are subject to study because of the unusual hydrochemical characteristics (pH between 10-12, high concentrations of Si, CH4 fluxes and certain thermalism, among others). In this work we will focus on the so-called epiperidotitic springs, that is, those whose pH is less than 10 and, therefore, have had less contact with the rock and circulate in a more open-semi-open system than that of the springs of pH greater than 10. Various water-rock interaction processes are proposed that explain different water families taking into account the hydrogeochemical parameters and the two large outcrops of Peridotites: Sierra Alpujata and Sierra Bermeja. Thus, a greater correlation between the contents of Si and Cr in Sierra Alpujata than in Sierra Bermeja is observed. The correlation between the pH and the saturation indices of minerals related to the serpentinization (Chrysotile, Nesqueonite and Brucite) is positive and high, which confirms an incipient serpentinization of some of the epiperidotitic springs. These two parameters (pH and saturation indexes) show an inverse correlation with PCO2, which indicates that there are waters that have circulated in a semi-open environment. The isotopic signal of dissolved inorganic carbon (13CDIC) is inversely related to most hydrogeochemical parameters. Waters with values closer to the atmospheric 13CCO2 (13CCO2 ~ -9 ‰) are waters of recent infiltration, with shorter transit time and less water-rock interaction, so their mineralization is low.
Evaluation and Optimal Management of Groundwater Resources (Bakhtegan-Maharloo basin)

Monday, 23 September 2019 16:00 (60)

Due to the lack of surface water resources in Bakhtegan-Maharloo basin, the amount of water withdrawn from groundwater resources has been more than the allowed limit. This amount has significantly affected surface water resources which led to some phenomena such as drying up of the Kor river, creating subsidence in 70% of basin plains, economic damages caused by reduction in the area under cultivation in downstream of kor river and drying up of Bakhtegan lake. In order to obtain a general view of this basin and optimal management of its groundwater resources, the situation of groundwater resources has been considered. In this regard, the unit hydrograph of basin plains and annual variations of the groundwater levels were studied. For preventing from further decline in the groundwater level some scenarios such as reducing the area under cultivation, changing cropping patterns, changing irrigation system and combination of these scenarios were presented. 19 out of 28 case studies which had 14 years (2002-2016) of groundwater level data were considered. The results illustrated that among 19 studied plains, all plains except Kherameh and Shiraz have the annual decline of more than 25 cm, also 68% of the plains have the annual decline of more than 50 cm, 47% of the plains have the annual decline of more than 75 cm and 26% of the plains have the annual decline are more than one meter. In this research, the plains more than 1 meter’s annual decline including Arsanjan, Kavar-Maharloo, Sa’adat abad, Sydan- Faroogh and Marvdasht with decline values of 2.43, 1.75, 1.44, 1.09, 1.02 meter respectively, were regarded as critical plains. At the next step, by taking into account the cultivation information, crop patterns, irrigation systems, and the volume of water-supply into the farm in pumping wells, four scenarios were performed and the annual decline under new conditions were calculated and compared with the prior annual decline. From the results, it can be expressed that only the use of modern irrigation systems instead of traditional systems in all or part of the dominant crops of the area under cultivation is not alone sufficient to reduce the available decline and will not compensate the major part of aquifer ’s annual decline of these fields. Therefore, it is necessary to change the major crop pattern into products with low water needs to be considered. The investigations showed that the second scenario (changing irrigation method for the available crop pattern) is operationally more appropriate among other scenarios but the third scenario (case b) (changing irrigation method and crop pattern Simultaneously) has a highest impact on compensating aquifer’s decline among all scenarios. In conclusion, according to the critical conditions of this basin the third scenario is suggested.

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Session Classification : Poster with refreshments
Track Classification : Topic 1 - Groundwater assessment and management
Natural CO2-rich springs emanate along an 80 km long North-South trending Fault in Eastern, South Africa. The geological units that outcrop along the Fault are the Dwyka Group rocks that are made up of mainly tillites and subordinate sandstone, shales and conglomerates. Hydrogeochemical, hydrochemical and environmental isotopes (δ2H, δ18O, 3H, δ13C and 14C) were used to characterise deep and shallow circulating groundwater along the fault. Groundwater and surface water samples at both CO2 emission and CO2 free streams, springs and boreholes around the Fault zone were collected and analyzed. Onsite physicochemical parameters including electrical conductivity (EC), total dissolved solids (TDS), pH, Temperature, DO, Eh, ORP, total alkalinity, CO32-, HCO3- at various surface and groundwater points were measured onsite. The results indicate that all deep circulating travertine cone springs along the fault zone are characterized by high salinity (EC > 6000 µS/cm), Na-Ca-Mg-HCO3 water type, depleted heavy stable isotopic signal with > 30‰ d-excess values, detectable tritium and dead 14C values. The δ18O versus δ2H stable isotope plot of the travertine cone springs shows a major negative shift from the meteoric water lines with δ18O and δ2H values ranging from -7.78 to -6.52 ‰ and -21.5 to -17.9 ‰, respectively. While, the shallow circulating groundwater and river samples show freshwater, Ca-Na-Mg-HCO3 water type, stable isotopic composition that reflect local and modern precipitation and < 18 d-excess values. These observations indicate that the reservoir and source of recharge for the deep circulating groundwater are different from the shallow groundwater and surface water.

A conceptual hydrogeological including inverse hydrogeochemical model is proposed to explain the deep circulation of groundwater and generation of CO2 along the fault zone and formation of travertine springs. The hydrogeochemical inverse model indicates that the major geochemical processes that are responsible for the observed hydrochemistry are the dissolution of calcite, dolomite, Pyrite, Goethite, K-feldspars, fluorite, albite and sylvite and the formation of calcite, amorphous silica, iron hydroxide, iron carbonates, kaolinite and CO2 gas. The inverse modelling results are supported by calculation of saturation indices (SI) for various mineral phases. The precipitation of calcite, amorphous silica and iron carbonates were validated by XRF, XRD and thin section analyses results of samples taken from the travertine cones.

Key Words/Phrases: CO2-rich springs, deep and shallow groundwater, Environmental isotopes, Hydrogeochemical characterization, eastern South Africa.
Numerical innovations in geological and groundwater modeling with unstructured meshes applied to underground works and complex geologies in Andean Mountains

Thursday, 26 September 2019 15:00 (15)

For hydrogeologists, the main challenge in underground works is to carry out estimation based on observed and inferred hydrogeological information with numerical expressions to calculate the seepage flow during excavation. Initially, analytical techniques were a basic and fast solution widely used. However, underground mining projects restrict their use due to complex geometric and geological conditions. Given this, current computational advances allow the integration of geological and hydrogeological knowledge; the use of specific software with flexible meshes is an example to estimate inflows, pressures and hydraulic heads variations in steady and transient conditions in underground works. Parallel calculation and continued innovations of the cloud platform gives us the tools with which to model more complex problems and faster estimations.

An application of current innovations in meshing and tools for groundwater modeling was applied in an underground mining project in South America with infiltration records > 400 L/s located in an area of high deformation with karstic and fractured conditions. A geological model was constructed in 3D Geomodeller to represent the complex geology in the Andes mountain range and generate the unstructured geometry with CGAL. Numerical modeling was implemented in FEFLOW with the TetGen algorithm to merge both complex geometries (i.e., geology and underground mine with galleries and tunnels > 150 km) and represent the current and future conditions in the mining project. Inverse modeling was done with FePEST to calibrate the current infiltration rates and several sensitivity analyses scenarios were done to identify the potential inflows and drawdown impacts according to the future construction plan of galleries and tunnels.

Keywords: FEFLOW, 3D Geomodeller, unstructured meshes, groundwater, inverse modeling.

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Session Classification : Parallel

Track Classification : Topic 5 - Tools, methods and models to study groundwater
Drainage galleries system to depressurize active landslide in unconfined aquifer located in the north of Bucaramanga, Colombia

Thursday, 26 September 2019 11:45 (15)

Landslides phenomena are natural hazards cause each year in the world fatalities and damages to buildings and infrastructures, in Mountains regions. However, the prediction of these with numerical models remains a major challenge for hydrogeologists. Meteorological, geotechnical, geological and hydrogeological properties of the environment must be known in detail to understand the landslide kinematics and make robust predictions according to conceptual models. An example occurs in the neighborhoods of the northern area of the city of Bucaramanga where more than 5.000 people are affected. Based on monitoring with inclinometers and vibrating wire piezometers, the relationship between groundwater systems and mass movements was evidenced in an unconfined aquifer of the Bucaramanga formation in the Northern zone of the city of Bucaramanga, Colombia. To provide a solution, a drainage system with shallow galleries was implemented according to the continuous monitoring of the piezometric levels. Numerical simulations were carried out in FEFLOW with a flexible mesh according to the conceptual and geological model and included unsaturated and saturated conditions in fractured media. The simulations permitted to understand the decrease of piezometric levels and seepage conditions to avoid a future landslide in the zone, complement geotechnical models and improve the safety and their quality of life of the people.

Keywords: FEFLOW, drainage galleries, landslide, monitoring, seepage.

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Session Classification: Parallel

Track Classification: Topic 5 - Tools, methods and models to study groundwater
Launch of the new Groundwater working group for implementation of the United Nations Framework Classification (UNFC)

Tuesday, 24 September 2019 15:30 (15)

During the recent Resource Management Week organized by UNECE (United Nations Economic Commission for Europe) in Geneva last May, aimed at the application of the official resource classification adopted by United Nations, namely UNFC (United Nation Framework Classification), a new working group exclusively dedicated to groundwater resources has been established, side to other historically existing working groups. This novelty is demonstrating the relevance of groundwater resources in the worldwide approach to sustainability. In fact, the UNFC is a universally acceptable and internationally applicable scheme for the sustainable management of all energy and mineral resources, with specific focus on minerals, raw materials, oil and gases, and more recently on renewable resources as solar, wind, geothermal. Furthermore, the UN adoption of the Sustainable Development Goals (SDGs) requires a modern management of earth resources based on sustainability also aimed at climate change mitigation. In this framework, where the existing UNFC is moving towards an extended classification named UNRMS (United Nations Resource Management Sustainability), a growing interest in groundwater resources has been raised. Peculiarity of groundwater resources respect with other earth resources is mainly due to the coexistence of renewable (due to annual recharge of aquifers) and not-renewable resources (long-term groundwater stocked in deep aquifers); this situation requires a preliminary validation phase to verify applicability of existing UNFC on groundwater resources. At the same time, the emerging approach based on sustainability, which implies not only focus on exploitation for human uses, but also on the environmental and ecological needs, seems to fit perfectly with the comprehensive concept of management and protection of groundwater resources. In addition, groundwater is a natural resource interested by transboundary flows, which implies application of modern policies and a solid governance to be efficiently managed.

Taking into account the UNFC, the activity of the working group to be developed in the following years is aimed to: i) enlarge the WG membership to ensure a worldwide representativeness; ii) check existing classifications adopted by single member states; iii) test the consistency of UNFC to groundwater; iv) submit a document explaining the Terms of Reference for the working group; v) bridging existing classifications with UNFC; vi) apply the UNFC to groundwater by case studies; vii) prepare the transition to the new UNRMS.

This ambitious program requires a solid knowledge basis, the involvement of groundwater experts and organizations, firstly IAH, and an efficient dialogue with stakeholders. In addition, synergies with other research programs, as EU projects (e.g. GeoERA), Unesco-IHP projects, and others, are mandatory. With these premises, the working group is open to worldwide contributions and collaborations to deal with the expected goals and to increase the relevance of groundwater issues and consequently of its community.

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**Session Classification:** Parallel

**Track Classification:** Topic 3 - Groundwater sustainability and governance
Understanding risks and resilience of private boreholes in Lagos, Nigeria

Tuesday, 24 September 2019 16:00 (60)

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

A broad internet survey shows that 68% of 500 respondents make use of private boreholes on a daily basis, either as their primary water source or used conjunctively with other sources. Attitudes to groundwater are overwhelmingly positive, with a majority considering this a reliable source in terms of quality and quantity, and agreeing that access to a private borehole increases households’ water security, helping families to cope with possible water shortages in future. The majority of borehole owners perceive no risks associated with long-term groundwater availability, with 89% agreeing that water is abundant and 86% holding the view that borehole owners should be able to abstract as much water as they like.

The results of a focused water-point and household survey, carried out at 40 private groundwater sources across Lagos, agree with these findings. Of those surveyed, the majority derive their domestic water from privately owned hand-dug wells and boreholes, and sachet water. Water point users have positive perceptions of the water quality from these sources, with 90% of boreholes and 80% of hand-dug wells thought to provide good quality water. However, water quality analyses show that individual’s perceptions do not always reflect reality. One third of boreholes and over 80% of shallow wells surveyed display unsafe levels of E. Coli. Of those sources perceived as good quality, almost 40% are classed as unsafe for drinking, according to measured levels of E. Coli.

The collective enthusiasm for unlimited and expanding groundwater extraction in the city of Lagos coupled with a demonstrated lack of groundwater governance and regulation, while increasing individuals’ resilience to issues of water shortage in the present, may decrease the resilience of the wider community in the long-term. Understanding the role of agency and communicating the potential risks associated with uncontrolled groundwater development, across a range of actors and agencies, may be critical to avoid future conflict between individual and societal resilience to environmental shocks.

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Session Classification: Poster with refreshments

Track Classification: Topic 3 - Groundwater sustainability and governance
Visual KARSYS – a web service for modelling karst aquifers

Thursday, 26 September 2019 15:45 (15)

Visual KARSYS is a web service under development and currently available at visualkarsys.isska.ch. Visual KARSYS addresses modelers (hydrogeologists, geologists, private companies, etc.) and end-users (administrations, NGOs, etc.) working for the documentation and/or the management of geology and groundwater resources in karst areas. It makes possible for modelers to setup projects, to entry geol. and hydrogeol. data and to design geological 3D model via the use of GmLib (developed by BRGM) in order to subsequently apply the KARSYS approach. On one side, Visual KARSYS offers an intuitive interface in which modelers are guided through the steps of the approach. On the other side, Visual KARSYS offers a dedicated output page for end-users which displays formatted data and resulting models built by modelers. Editing and reading permissions can be allotted by the project administrator to different users (both modelers and end-users). End users can arrange data and results as they want (form, layout, views, etc.) and different analysis tools are at their disposal (slicer, drawing tool, etc.). They can export different data or print maps.

Main developments on Visual KARSYS will end in June 2019. At that time the web service will be available for everyone. Perspectives for potential extensions to Visual KARSYS do exist in the field of karst hydrology (karst conduits generating, flows modelling, etc.) but also in a broader geological field (for instance: volcanic areas, glaciology, etc.). The Visual KARSYS project is supported by the Swiss Federal Office for Environment via the grant for the promotion of environmental technology (2016-2019, UTF 537.13.16).

A short course dedicated to the learning of KARSYS via the use of Visual KARSYS will be organized on Sunday 22nd September, 2019, in the frame of the 46th IAH congress.

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Session Classification : Parallel

Track Classification : Topic 7 - Karst Hydrogeology
Climate change is just one of many examples of how humans have negatively impacted Earth through the introduction of pollution in its many forms into the natural environment. Other impacts caused by pollution that may not be in the public eye as often but that are also significant include impacts to the land, oceans, surface water, groundwater, and the biosphere. Each are related and affects the others in a complex web that involves the interaction and physical and chemical dynamics of human interaction with the natural world.

Quantifying anthropogenic impacts on a global scale has only recently been available through new technologies and research but the data clearly demonstrates that anthropogenic impacts are substantial and are getting worse. However, now that the many aspects that have caused much of the environmental degradation have been identified, we can now move to action to reduce those impacts.

To reduce further environmental degradation, action must be undertaken at the global level, national level, state and municipal level, and the individual level. The actions must include many aspects of how humans behave and treat the Earth and involve changing our lifestyle through modifications of transportation, energy needs, shelter, and agriculture. Modifications at the global level may be the most difficult but are the most important because pollution does not respect political boundaries. Pollution from one country often migrates and affects all environmental media of other countries and sometimes the entire planet.

In order to support a human population on Earth we must not consume and pollute at current levels. In order to achieve a sustainable living, vibrant, and diverse world instead of a world without humans, we need to diligently work cooperatively towards living in productive harmony with nature instead of trying to change nature.

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Session Classification : Poster with refreshments

Track Classification : Topic 3 - Groundwater sustainability and governance
Radioargon Dating with Atom Trap Trace Analysis

Tuesday, 24 September 2019 16:00 (60)

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The noble gas radioisotope 39Ar (half-life = 269 yrs.) is the only reliable dating isotope for water and ice in the range of 50-1,400 years, a time range particularly important for tracing ocean circulation, groundwater and alpine glacier ice [3]. However, its use especially in oceanography has been hampered by the large sample size required by Low-Level Counting, so far the only available detection technique for 39Ar.

Atom Trap Trace Analysis (ATTA) is a laser-based atom counting method with ultra-high selectivity and sensitivity that has been developed for analyzing the environmental isotope tracers 85Kr and 81Kr [1]. Its realization for 39Ar presents a major challenge due to its extremely low abundance of only 8×10^(-16) [2], which is more than 800 times lower than for 81Kr. The applicability of ATTA to 39Ar has been demonstrated in a proof-of-principle experiment [4]. Practical dating of groundwater and ocean samples could later be demonstrated with 39Ar count rates reaching up to 7 atoms/h [5, 6].

Here, we present the latest status of the ATTA system for 39Ar at the USTC. We currently achieve an atmospheric 39Ar count rate of 10 atoms/h. In order to obtain a higher 39Ar count rate, together with the Institute of modern physics in Lanzhou we are working on 39Ar pre-enrichment. In preliminary tests, we could demonstrate an enrichment by a factor 10. We plan to test the water samples in a few months.

Keywords: Laser, Argon, Isotope Trace

Presentation Type: Poster

References

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Session Classification: Poster with refreshments

Track Classification: Topic 5 - Tools, methods and models to study groundwater
Water quality characterisation and Health risk assessment of Maputland coastal plain, KwaZulu-Natal, South Africa

The living population in the Maputland coastal plain largely depends on the groundwater derived from the unconsolidated aquifers through the shallow household and agricultural wells. Along the entire Maputland coast, around 51 groundwater samples were collected from these active wells and were analysed for major ion and trace elements such as Al, As, Co, Cd, Cu, Fe, Mn, Pb and Zn. Various interpolation methods were applied in the study to understand the suitability of water quality for drinking & irrigation purposes and the evolution of water quality by geochemical characterization. The health risk assessment was also carried out. Rock-water interaction and Na/Ca ion exchange are the dominant processes responsible for the characteristics of the water quality in the study area. The results revealed that the water quality is suitable for irrigation purposes while for the drinking purpose, about 22 %, 2 %, and 7 % of the samples fall under the poor, very poor & unsuitable class respectively, with the spatial distribution seen towards the southern and western part. The health risk assessment interfered that the hazard quotient for ingestion, dermal & hazard index of Co and HQ dermal & hazard index of Cd, As and Mn pose serious to adverse risk to local people on exposure for a longer period while Infants are predicted more vulnerable to health risk than children and adults. The study suggests long term monitoring for health risk and crop yield to minimize the negative impact due to poor water quality.

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Session Classification : Parallel

Track Classification : Topic 8 - Groundwater quality and pollution processes
Improving Groundwater-Surface Water Modeling by Integration of Rain Gauge and NEXRAD Data

Rainfall is the most influential factor affecting groundwater and surface water regimes. Spatial and temporal characteristics of rainfall events significantly impact the partitioning of rainfall into runoff, infiltration, and groundwater recharge, and thus the dynamic water exchange between groundwater and surface water. Integrated hydrologic models simulate surface water and groundwater processes and their dynamic interaction using rainfall directly as an input. A network of rain gauges coupled with a spatial distribution process is often used to define the temporal and spatial distribution of rainfall over a model domain. The ability for a rain gauge network to capture key characteristics depends on the density and recording frequency of the network and the dominance of convective storms. Where the surface and groundwater systems are dynamically coupled, an integrated model is a valuable tool to evaluate changes in groundwater and surface water resources due to many causes including rainfall variability and changing climate.

Using a 4,000 square mile region of west-central Florida as a case study, integrating rain gauge data with NEXRAD radar rainfall data is demonstrated to enhance the estimation of historical rainfall and has resulted in improved hydrologic responses from an integrated hydrologic model of the region. The model application is based on the Integrated Hydrologic Model code which dynamically couples the HSPF surface water model and the MODFLOW groundwater model codes. The integrated model was previously calibrated using historical rainfall inputs that were estimated from rain gauge data only, with spatial distribution approximated by the Thiessen polygon method. Using a Bayesian statistical approach (described in a companion abstract), rain gauge and NEXRAD radar data sources were integrated to improve the estimation of historical rainfall from 1995 to the present time. Subsequently, integrated hydrologic model simulation was performed using the integrated rainfall inputs. The results show improved matching with observed flows and levels data that were used in model calibration. Model parameters were adjusted to further improve model performance. Model performance using the gauge-only and NEXRAD-only rainfall estimates is compared to the performance of applying the improved rainfall estimates.

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Session Classification : Parallel

Track Classification : Topic 5 - Tools, methods and models to study groundwater
The delineation of hydraulic conductivity (K) heterogeneity is essential to support effective remediation of environmental sites and sustainability management of groundwater basins. However, K characterization by conventional methods is a difficult and expensive task at sites with complex hydrogeology. Inadequate K characterization has resulted in poor remediation performance at many legacy environmental sites and excessive potentiometric head decline at many over-drafted wellfields. Recently, a technique based on sequential pumping tests and stochastic hydraulic tomography (HT) inversion using successive linearization estimator (SLE) has been demonstrated to be effective for delineating K heterogeneity. The HT technique was initially developed to treat the K-distribution in a groundwater model as a correlated random field and to invert the model stochastically using the hydraulic head response data from individual aquifer pumping/injection tests. Although many environmental sites with pump-and-treat systems and water suppliers with production wellfields have collected an abundant amount of operational and monitoring data, sequential pumping tests by temporarily shutting down individual wells might not have been performed. Performing such tests might not be possible due to operational constraints. Even if they have been performed, the duration of operational changes might have been too short. The monitoring data during a temporary operational change always contain the complex signature of previous operations prior to the change. Although all historical data can be theoretically utilized for HT inversion, the computational effort needed is practically infeasible.

We will present a computationally efficient approach based on a combination of Transfer Function Noise (TFN) analysis and Hydraulic Tomography (HT) analysis to estimate the spatial K-distribution and the associated uncertainty using abundant extraction/injection operational and monitoring data. We will use the operation and monitoring data collected at an environmental site in Arizona as an example. The TFN technique can be applied to estimate the hydraulic head response to constant-rate pumping/injection at each relevant well through convolution integration. Such step-response functions are equivalent to the data collected from individual aquifer pumping/injection test without carrying any long-duration pumping/injection operations signals and can be utilized directly in HT analysis. We will present an efficient approach to simplify the HT computations by incorporating principal component analysis (PCA) to reduce the numbers of parameters and the number of calibration targets. This method allows for the removal of both parameter and calibration target dependencies without losing significant information. In addition, we will present a Markov Chain Monte Carlo (MCMC) approach for HT inversion. This approach can be easily adopted to use any forward simulation models.

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**Session Classification**: Parallel
Track Classification: Topic 5 - Tools, methods and models to study groundwater
Quantifying the potential seepage from the Quillayes porphyry Cu tailing dam using stable isotopes (Chile)

Thursday, 26 September 2019 16:00 (60)

Chile is extraordinarily enriched in porphyry-style copper deposits and is the largest Cu producer worldwide. Mining activities of these ores, which are characterized by low Cu grades and high tonnages, produce several environmental footprints, as large amounts of tailing production and disposal in dams, and seepage of tailing dam waters towards the neighboring aquifers. The tailing dam managements usually includes different strategies to minimize seepage towards groundwater, such as drainage ditches and pumping wells installed as hydraulic barriers. Nevertheless, these strategies are not always sufficient to avoid seepage waters, and there is a growing interest to develop tools to trace and quantify the impact of tailings in groundwater. In the present study, isotope data ($\delta^{2}H-\delta^{18}O-H_{2}O$ and $\delta^{34}S-\delta^{18}O-SO_{4}^{2-}$) from the hydric systems related to the Quillayes tailing dam (from the Pelambres porphyry Cu deposit) have been studied to illustrate their potential as tool for quantifying tailings seepage contribution to groundwater.

The isotope signature of the Quillayes tailing dam waters projects far from the local meteoric waters, suggesting that waters are affected by evaporation. The isotopic composition of groundwater samples collected downstream from the Quillayes dam plotted in the calculated evaporated trend, suggesting a mixing at different proportions of highly evaporated water from the tailings dam and local meteoric waters. Those groundwater samples located closer to the dam showed a mine tailing water contribution ranging from 40 to 80 %, whereas groundwater samples located farther and downstream from the dam had a tailing water proportion lower than -20 %.

The dissolved sulfate may originate from: i) oxidation of ore sulfides; ii) dissolution of primary ore sulfates (mainly anhydrite); and iii) fertilizers used in farmlands. A mixing model using the $\delta^{34}S-\delta^{18}O$ of SO$_4^{2-}$ showed that tailing dam water (> 2 g/l SO$_4^{2-}$) had higher contribution of SO$_4^{2-}$ from the dissolution of primary ore sulfates than sulfide oxidation. Furthermore, the $\delta^{34}S$ and $\delta^{18}O$ signatures of dissolved sulfate in the surface water (13-191 mg/l SO$_4^{2-}$) are consistent with a high influence of sulfate from sulfide oxidation. On the other hand, the $\delta^{34}S$ and $\delta^{18}O$ of SO$_4^{2-}$ in groundwater downstream from the Quillayes dam suggests a mixing at different proportions of dissolved sulfate from the tailings dam and natural waters. The groundwater closer to the dam (1.0-1.5 g/l SO$_4^{2-}$) showed a sulfate contribution from the tailing dam between 70 and 90 %, whereas farther to the dam groundwater (200-700 mg/l SO$_4^{2-}$) had a tailing sulfate contribution lower than 60%.

This multi-isotopic study has permitted to quantify the contributions from dam tailings and natural waters in the aquifer downstream from the Quillayes dam, showing a higher contribution of dam tailings waters in groundwater closer to the dam than those located downstream.

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Quantifying the potential seepage...

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**Session Classification:** Poster with refreshments

**Track Classification:** Topic 9 - Groundwater and socio-economic development in Latin-America
Spatial controls on groundwater quality in Sierra Leone: moving towards a national data management framework?

Monday, 23 September 2019 16:00 (60)

West Sub-Saharan Africa is one of the regions most affected by global change, with predictions of rainfall deficit over the next 50 years (World Bank Data). Post-civil war demographic boom, combined with increasing water demand to boost the agricultural and mining sectors have highly challenged the current capacity of post-colonial infrastructures to supply the needs in drinking water. Moreover, the assessment of groundwater as an alternative source across the country is still very limited to local and regional studies. Well data from over 475 well locations from around Sierra Leone was compiled from third-party sources including NGOs, drilling companies and government agencies. Relevant chemical data from 86 of those well locations were discovered and analyzed in order to find relevant spatial correlations between groundwater quality, demographics, population density and land-use patterns. Preliminary results suggests that 1) biological contamination shows a positive spatial correlation with predominantly agricultural land-uses and a low dependency on human density, 2) physicochemical parameters (TDS, turbidity) are likely associated to proximity of major transportation lines, and 3) trace metals (copper, iron, manganese) contamination suggest a natural (geologic) signature. A danger scale for chemical contamination was computed and will be useful to target the most vulnerable regions. A major obstacle to the development of this project is the lack of a national groundwater data framework. The development of a national groundwater database is crucial to analyze the sustainability of current groundwater uses and will be useful to inform future sustainable management of the resource.

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Session Classification : Poster with refreshments

Track Classification : Topic 3 - Groundwater sustainability and governance
Currently, the Júcar River Basin District has 25 groundwater bodies (24%) that exceed the quality norm on nitrates. These bodies are mainly located on the coastal areas of the basin district.

In the 1980s, an excessive increase of nitrate concentration occurred, attaining, in the present days and in certain areas, values of up to 200 mg/l. These high values can undermine the achievement of the good status of those water bodies.

It is necessary to mention Council Directive 91/676/EEC of 12 December 1991 concerning the protection of waters against pollution caused by nitrates from agricultural sources, transposed into the Spanish legal order by means of Royal Decree 261/1996. This Directive has the objective to reduce pollution caused by nitrates from agricultural sources and to take preventive action against new pollution from these sources, while imposing the obligation on member states to identify water bodies that are affected by nitrate pollution from agricultural sources, or at risk of being affected.

As laid down in the regulations in force, vulnerable areas to nitrate pollution from agricultural sources are classified by the regions (Comunidades Autónomas in Spain) in their respective fields, while affected water bodies are identified by the central administration. The order in the designation is such that the affected waterbodies are designated first, followed by the vulnerable areas.

In addition, the regions are entrusted to draft the action plans and programmes, including enhanced agricultural practices. The observed evolution of nitrate concentration on water bodies, reveals that it is necessary to foresee additional measures such as establishing nitrogen inputs, applied according to the quality of the irrigation water. The river basin management plan, approved by Royal Decree, can be an essential tool to establish those measures.

In order to do so and due to the fact that the competences are shared between the different administrations, it is necessary to set up coordinating measures between them. Indeed, whilst the regional administration is competent for issues related to agriculture and farming, the central administration, through the respective basin authorities, is responsible for the management of the Water Public Domain.
Seasonal Catchment Water Balance Using Storage-Discharge Relationships

Monday, 23 September 2019 16:00 (60)

Mountainous areas provide important sources of fresh water for adjacent lowlands. However, hydrogeological and hydrometeorological complexities of mountainous catchments, make reliable seasonally estimation of catchment water balance components challenging, such as the evapotranspiration (ET), subsurface lateral flow (L) in the dry season and catchment water storage change of the wet season. In this study, an improved method based on storage-discharge relationship (SQL) is proposed to estimate seasonal catchment water balance for mountainous catchments. In comparison to the previous approach, the improved SQL method has incorporated the subsurface lateral flow.

The improved SQL method was applied over six catchments with various sizes, climatic and hydrogeological conditions in the Mount Lofty Ranges (MLR) of South Australia. ET estimate for the six catchments agrees well with that from the method based on surface reflectance from MODIS-Terra and interpolated climate data, suggesting that the improved SQL method can be an alternative approach for catchment water balance quantification in mountainous regions. The improved SQL method, only based on continuous streamflow data, provides estimation of inter-annual variation of ET and subsurface lateral flow in the dry season, and catchment water storage change of the wet season. For the dry season, it is critical to understand the contribution of the subsurface lateral flow to the region, which may be the main water sources to the adjacent catchments. For the wet season, it is of importance to know that how much water has been left in the catchment for sustainable water sources management.

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Session Classification : Poster with refreshments

Track Classification : Topic 1 - Groundwater assessment and management
A tool box for managing karst

Thursday, 26 September 2019 17:45 (15)

Karst environment is subject to specific problems such as flooding, collapses/sinkholes, or water contamination. All are strongly associated to water. A good knowledge of the distribution of heads and fluxes in space and time would help a lot to predict and manage those problems. Ideally karst hydrogeologists would like to know water heads and fluxes anywhere in the karst system! Many studies are however focused mainly either on the time aspect (e.g. time series analyses) or on the spatial aspect (e.g. geophysics). Some modelling approaches are proposed to link both aspects together, but the required effort is huge and often reserved to academic work or to a few big projects.

A series of karst-specific approaches are being developed by SISKA in order to provide this type of information within a reasonable effort (Karst Toolbox).

KARSYS is based on a 3D geological model of the karst aquifer, including hydrological data explicitly. This approach provides a concrete sketch of the main drainage axes, of the expected heads and on the supposed catchment area. A tool is now available on the web to apply this method on-line for any system in the World.

Adding a model of the speleogenetical conditions and on the inception horizons to the KARSYS model makes possible to predict the potential position of karst channels as well as their characteristics for any type of underground construction. This is KarstALEA, which can be expanded to near-surface in order to identify the potential position of sinkholes and collapses.

KarstFLOWSIM is being developed in order to be able to simulate heads and flow in a karst environment. The simulation process includes the assessment of effective recharge (evapotranspiration processes) as well as the hydraulics of flow in a partially saturated pipe network. Various levels of details can be used in KarstFLOWSIM, requiring a more or less precise description of the karst conduit network. This module is used for flood assessment.

KarstNETGEN is being developed to generate karst conduit networks within the 3D geological model, considering probabilities inferred in the KarstALEA model. Compared to other generators, it takes explicitly into account the spatial distribution of recharge (zones of diffuse or concentrated recharge), as well as concepts of speleogenetical levels and inception horizons.

KarstVULN is a way to assess groundwater vulnerability to pollution. It will include information of KarstINDIC, which is a map of the main characteristics of the near-surface of a karst region (karst cover and geomorphology).

The sketched Karst toolbox is being developed first and mainly for karst region in temperate and mountainous regions (as we have in central Europe). Adjustments and extensions for other contexts (e.g. lowland karst or hypogenic karst areas) should be discussed.

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Session Classification: Parallel

Track Classification: Topic 7 - Karst Hydrogeology
Groundwater Project and eBooks: An Evolving Platform for Groundwater Education and Practice

Monday, 23 September 2019 14:20 (30)

Groundwater is the source of drinking water for nearly half of the global population and supplies much of the world’s irrigation water. Groundwater is complex, out-of-sight and mostly out-of-mind. The GWP (Groundwater Project) is urgently needed to ensure that society achieves the exceedingly difficult task of scientifically-informed, sustainable management and protection of groundwater. The goals of the (GWP) and its eBooks are to publish educational materials, online and free-of-charge. The first iteration will be in English, followed soon after by other languages. The GWP was initiated 3 years ago to cover nearly all aspects of groundwater relevant to both developed and developing countries. The non-profit GWP will fill large voids in educational publishing to become the global standard for synthesized groundwater science. ‘Publishing’ of the first few dozen chapters on the GWP web site will begin in late 2019. Nearly 400 chapters, organized in ~40 ‘knowledge domains’, are planned for the next few years. Many chapters will be layered to support understanding at both introductory and advanced levels with clickable links to equation derivations, worked problems, public domain educational reports, videos of lab demonstrations, field methods, and lectures. Each domain with its chapters is a book within the series of eBooks. The first is for readers with no science education, followed by a book at the undergraduate to graduate level concerning all of the important physical principles and theory. Then there is a book covering the important chemical and biochemical principles. These two books are the foundation for many others on applied topics and interfaces with other disciplines including ecology, human health and social sciences. Although encyclopedic in scope, the GWP is focused on knowledge synthesis to achieve understanding, underpin classroom teaching and facilitate self-education. The eBook aims to provide explanations from experts who are so advanced in their grasp of complex topics that they can convey ideas in impressively simple form. As of May 2019, more than 120 volunteers from 15 countries on six continents are involved in preparation of eBook chapters while the search for more participants continues. Many contributors are internationally recognized experts. A priority is to capture, while still possible, knowledge and key insights from this senior generation. The GWP will also serve as an electronic archive for old, but still insightful groundwater reports from government and other literature not readily accessible, or in jeopardy of being lost. In addition, the GWP will report on the latest advances in groundwater science and technologies to quickly disseminate new knowledge around the globe, including emphasis on the information needs of developing countries. The electronic format was selected for the GWP because materials will be updated and re-published as improvements are made and as global contributions expand.

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Session Classification : Plenary
Track Classification: Topic 1 - Groundwater assessment and management
Alicante Province, with an area of 5,817 km², is located in the SE of Spain. It ranks as the 4th most populous province of the fifty into which Spain is divided. From the middle of the last century, it has experienced an important economic development due to the transformation from rainfed to irrigated agriculture, as well as to the increase of tourism and industry. The scarcity of superficial resources in the region has made groundwater to have been a basic resource to supply water for these activities.

Regarding hydrogeological features in the province most of the aquifers are carbonated. There are mainly Cretaceous limestones and dolomites, but also Tertiary calcarenites, sandstones and limestones and Jurassic limestones and dolomites. There are also some detritic aquifers but not only their extension is smaller but also have worse hydraulic characteristics and in some cases poor quality water. Broadly speaking, the North-East and the South-West areas of the province are two differentiated domains. The first one has larger carbonatic aquifer systems under more humid climatic conditions, with average annual rainfall ranging between 500 and 900 mm. Thus aquifers have significant recharge rates and greater resources. On the other hand, in the South-West, where the carbonate aquifers are smaller due to the high tectonic compartmentalization and with rainfall annual averages ranging between 250 and 400 mm, recharge rates and so resources are scarce. Therefore, these areas concentrate the main overexploitation problems, specifically the basin of river Vinalopó.

In general, the quality of groundwater for current uses vary from good to excellent, with a predominance of bicarbonated calcium-magnesium facies related to the numerous carbonate aquifers. However, in the southern half of the province and in some aquifers in connection with the sea the quality is insufficient for practically all use, due to mineralization problems.

Provincial total input is currently estimated to be about 445 hm³/year-1, with a difference between inputs and outputs of 28.5 hm³/year-1 in average. This latter figure is considered the overall groundwater overexploitation in the province, which is nearly half than ten years ago. This reduction is the result of a series of factors such as the arrival of external flows, the improvement of the efficiency of irrigation and supply networks, as well as infradotation to irrigation, or even abandonment, of some uses due to insufficient supply in quantity or quality. However, the natural scarcity exposed causes that the moderate to small recharge rates are incapable of balancing the intensive extractions that have taken place for decades.
Analysis of piezometric trends in the Medina del Campo Groundwater Body to understand the status and drivers of changes of groundwater-related ecosystem services. NAIAD EU Project

Tuesday, 24 September 2019 16:00 (60)

The area covered by the Medina del Campo Groundwater Body (MCGB, Duero River Basin, Spain) is an important agricultural production region. Groundwater is the main provisioning source for irrigation, to supply many small towns and also to support surface groundwater-related ecosystems (SGRE). The area is prone to climatic and geomorphological hazards such as floods and droughts. The aquifers is formed by a tick (100 to > 500 m) accumulation of Tertiary fine-sized alluvial, eolian and lacustrine sediments. Groundwater levels have declined up to 20 m in some areas in the last 40 years. In the framework of the NAIAD H2020 project, we are analysing the role of groundwater-related ecosystem services for drought hazard mitigation and to support SGRE, in a context of increasing climatic variability and testing different management strategies. The objective of this work is to understand the evolution of some provisioning and regulating ecoservices and its causes, based on the analysis of temporal piezometric trends. The Mann-Kendall test has been used to analyse the temporal trends of piezometric and precipitation time series in the MCGB for the period 1985-2018. The results have been studied on a regional scale with the support of GIS. The study was based on data from 137 piezometers and 10 meteorological stations. The analysis was performed for two-time intervals based in the different lengths of the piezometric series available: 1985-2001 and 2002-2018. A clear and generalized decreasing piezometric trend has been identified for the interval 1985-2001. For the interval 2002-2018, many piezometers show a clear increasing trend while others do not show any tendency. Some punctual (both spatial and temporal) correlations have been observed between decreasing piezometric levels and decreasing precipitation but given the characteristics of the aquifer and the piezometers, this is attributed to augmented pumping to complement the soil water deficit on dry years. The observed general piezometric trends are attributed mostly to the effect of groundwater management actions after the entry into force of the Water Framework Directive. The study is still under development.

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Session Classification : Poster with refreshments

Track Classification : Topic 5 - Tools, methods and models to study groundwater
Anthropogenic activities constitute a major threat to groundwater resources if not monitored and controlled and thus may hamper the optimum harness and utilization of the scarce resources. Most groundwater resources evaluation focuses on delineation of the water bearing unit and less attention is centered on the quality and vulnerability of the resources. It is on the latter that the focus of this paper is based.

Field measurements using electrical geophysical methods was adopted for the study and sixty five vertical electrical sounding (VES) data using schlumberger array method were acquired. The computer assisted VES data interpretation enables the delineation of the subsurface into three to four geoelectric layers: the topsoil, the lateritic or weathered layer, the fractured basement and the resistive bedrock. In the topsoil, resistivity values range from 20 ohm meters – 580 ohm meters with the layer thickness varying from 0.4 m – 2.0m. The second layer which is presumably the weathered zone, has resistivity in the range 21 – 648 ohm meters with the thickness ranging from 0.3 m to 36.6 m. The fractured bedrock has resistivity in the range 36 ohm- m – 796 ohm meters. Geoelectric layers with relatively low resistivity values are considered zone of saturation which are the potential target for groundwater resources.

Assessment of the vulnerability potential of the aquifer especially the topmost aquifer was based on the geo-electric parameter evaluated from the resistivity data. Aquifer overlain by topmost layer with low resistivity (< 100 ohm-m) has been interpreted to imply clayey formations with good protective capability and less vulnerable. This occupies most of the central part and the southwestern part and constitutes about 65% of the study area. Aquifers within the zones overlain by geoelectrically pervious materials (resistivity of 101 to 300 ohm meters) interpreted to be sand around the northern part and some portions of the southern part of the study area is about 35%. This is considered vulnerable to infiltrating surface contaminants.

The study has made possible the characterization of the vulnerability potential of the aquifer in the study area. The area is mostly covered by materials of thin protective capacity top layer with pockets of weak protective topsoil (sandy). This makes the groundwater resources in the area vulnerable to surface anthropogenic source pollution. However precautionary measures to protecting the resources must be put in place by the local municipal authority for adequate monitoring of waste disposal by individuals and factories in the area.

Key words: Groundwater, Electrical sounding, Resistivity, Aquifer, vulnerability.

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Session Classification : Poster with refreshments
Track Classification : Topic 1 - Groundwater assessment and management
Hydrochemical and isotopic multi-tracer data to characterize subsurface upwelling of saline groundwater along conductive fault zones

Thursday, 26 September 2019 12:15 (15)

Existing studies showed that conductive fault zones within carbonates and evaporites (gypsum/anhydrite, rock salt) may act as a bypass for both the access of subsaturated groundwater to vulnerable rock salt formations and the transport of the resulting brine into near-surface aquifers (Zidane et al., 2014). As a consequence, rock salt karst develops more likely near the conductive fault zones, which may lead to land subsidence above the fault zones. However, mapping and hydraulic characterization of subsurface fault zones is often not possible due to the lack of relevant data. The presented multi-tracer study in the regional Middle Triassic carbonate aquifer of Northwestern Switzerland aims at delineating areas, where upwelling of saline waters suggests the presence of conductive subsurface fault zones. A total of 60 groundwater wells reaching depths between 10m and 270m were sampled for physico-chemical parameters, hydrochemistry (major ions and trace elements), and water isotopes (18-O, 2-H, 3-H, 13-C, 14-C, 34-S, 87-Sr/86-Sr). The multi-tracer data was structured with multivariate data analysis tools such as principal components analysis, and compared to simulated groundwater flow velocities from a 3D groundwater flow model from the aquifer system.

Data of 34-S composition together with sulphate concentration were used to distinguish between dissolution of gypsum/anhydrites aquitards lying either above, or below the Middle Triassic aquifer. Isotopic tracer information used for groundwater age determination found that large parts of the aquifer have been subjected to mixing between very recently infiltrated rainwater, infiltration from the nearby river Rhine, and existing older Holocene, or Pleistocene groundwater (>10’000 years). The mixing process is accelerated due to both large-scale groundwater pumping and artificial groundwater recharge, which significantly increase flow velocities in affected parts of the aquifer as confirmed by groundwater flow simulations. Also the observed distribution of sampled chloride concentrations ranging from a few 10s of mg/l to several g/l is influenced by the accelerated mixing process driven by artificial groundwater recharge and groundwater withdrawal. Mapping of conductive fault zones with groundwater sampling appears therefore more appropriate in areas with less anthropogenic influence to the groundwater flow field, which corresponds to sampled areas with low groundwater flow velocities.


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Session Classification : Parallel
Track Classification : Topic 5 - Tools, methods and models to study groundwater
Much has been done and is still being done regarding the study of transboundary aquifers. Organizations such as UNESCO and OTCA have made great efforts in studying the worldwide situation. Such efforts have resulted in improving the knowledge about these aquifers and their complex relationship with water resources, society, ecology and politics. However, there are areas where remoteness hampers gaining knowledge and developing studies, such as in the western Amazon region. From 2011 to 2013, Brazilian researchers from UFRJ, working together with Spanish specialists from UPC, gathered and synthetized geological and hydrogeological data on western Amazon, in South America, which a transboundary multilayer aquifer. Data was integrated into a Geographical Information System (GIS) and a Visual- MODFLOW-3D simplified numerical model was constructed. The about 2.7·106 km² Tikuna Aquifer conceptual flow system was identified and preliminary characterized. It extends from the Subandean Amazon area, where recharge is produced in rainy areas and probably by infiltration of melt glaciers waters. Groundwater flows through Cretaceous layers, attaining depths over 2 km. Groundwater partially outflow in some points of the Peruvian basins of Marañón and Putumayo, according to the numerical model. Results explain the evidences from fieldwork. Groundwater partially flows to the Brazilian territory to finally outflow and recharge the Alter do Chão aquifer, which is the most known subunit of the Amazon Aquifer System. The Tikuna aquifer boundaries were identified and stratigraphic data of the seven sedimentary basins that form this aquifer could be merged to define the aquifer. Hydrochemical data were also used for a better understanding of groundwater characteristics. The initial step has been done and new extension are in course, but further studies are needed and have been identified, especially considering the relationships between surface and groundwater in the complex Amazonian ecosystem and the future challenges posed by climate variability and the effects of the possible climate change previsions.

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Session Classification : Parallel

Track Classification : Topic 9 - Groundwater and socio-economic development in Latin-America
A smart soil and groundwater contamination transport simulation system

Soil and groundwater contamination has been and continues to be a significant concern for many industrial sites. The presence of contaminants in groundwater poses severe risk to human health and impacts water resource sustainability. A reliable simulation of contamination reactive transport is desired for most industrial pollution management. A smart system is constructed for soil and groundwater contaminant estimation and prediction in our group with artificial intelligence. The system consists of four main parts: database construction, model generation, forward simulation, and inverse modeling. With site related hydrogeologic and atmospheric data, both concept and numerical model are generated automatically in the system. The model is able to simulate the contaminant reaction and transport from point or non-point pollution in the subsurface system. By collecting real-time wireless data from the sensors on site, the model itself and parameters in the model are spontaneously adjusted to enhance the model accuracy and precision. Thus, this smart system can provide an early warning showing when and where there are large changes in hydraulic or contaminant situation. By improving our understanding of how the contaminants are interlinked and driven by the hydrogeology conditions, we could avoid or reduce environmental risks at contaminated sites.

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Session Classification : Poster with refreshments

Track Classification : Topic 5 - Tools, methods and models to study groundwater
ECOHYDROLOGY STUDY IN THE BOGOTÀ SAVANNAH USING ISOTOPE ANALYSIS AND NUMERICAL MODEL

The aquifers of the Bogota Savannah have been intensively pumped since the last century for agriculture, industry and domestic use, generating effects such as the mechanical collapse of wells and the descent of the water level of up to 250 m in some areas.

The main objective of the study was to apply isotope hydrology to calculate water age and water travel times in Guadalupe and Quaternary geological formations as a tool for calibration of the hydrogeological model and the impact on the ecology of the landscape in the Savannah of Bogota.

The calibrated hydrogeological model was used and adjusted with the results of the analyses made with isotopes (carbon 14, oxygen 18, tritium and deuterium), hydrochemistry, geophysical information and satellite images of the area.

The current Carbon-14 results show water age for the subsystem of the Cretaceous aquifer of the Guadalupe formation between 2000 and 23,000 years, and that the foothill area is mostly a recharge area, as confirmed with tritium. The ages were used to adjust the numerical model, obtaining travel times according to the isotopic information. The lower part has a lithology with very low permeabilities. Although isotope information is not as abundant, it was possible to have a more adjusted model, which increases the knowledge of the groundwater flow in the aquifer systems in the Bogotà Savannah.

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Session Classification : Poster with refreshments

Track Classification : Topic 5 - Tools, methods and models to study groundwater
Groundwater recharge sources in the Gandak alluvial aquifer, NE India: how important is leakage from irrigation canals?

Monday, 23 September 2019 16:00 (60)

There is ongoing debate around the status of groundwater in the Indo-Gangetic Basin (IGB) alluvial aquifer, which as a whole is the world’s most heavily exploited aquifer. There is clear evidence for over-abstraction and/or contamination in some parts of the aquifer, but other areas do not show the same intensity of human impact. The hydrogeology and external influences on groundwater across the IGB aquifer are complex and diverse. Influences include increasing groundwater abstraction, changes in land use and other economic behaviour, and the impact of the network of engineered irrigation canals that distribute river water across many catchments. The role of leakage from irrigation canals is now a fundamental part of groundwater dynamics in the IGB aquifer. Recharge to some areas of the aquifer contains a high proportion of canal leakage (Joshi et al. 2018), but to others it is much less (Lapworth et al. 2015).

The Gandak catchment, in the northern part of Bihar state in NE India, provides an excellent laboratory for studying the evolution of groundwater-river-canal dynamics in the centre of the Ganges basin. Evidence shows no overall long term declining groundwater level trend in the Gandak alluvial aquifer (MacDonald et al. 2016, CGWB 2016), such as is seen in some other parts of the IGB aquifer. Our study, carried out as part of the joint UK-India funded CHANSE project, is the first detailed investigation of the Gandak aquifer.

We used isotopic, residence time and geochemical tracers to quantify the contribution of recharge from canal leakage, the Gandak River and local monsoon rainfall; and to characterise groundwater flow and mixing behaviour. We show that canal leakage has been a significant source of aquifer recharge since at least the 1960s, but that this is restricted to shallow depths, above ~30 m. Deeper groundwater, below 30 m, shows no evidence of canal or river leakage, but is consistent with long term active recharge from local monsoon rainfall. Groundwater in the shallow zone shows more chemical and isotopic variability than in the deeper zone. This is different from other studied parts of the IGB aquifer, where deep groundwater has been shown to be significantly impacted by over-abstraction and groundwater pollution. These differences are partly linked to hydrogeological conditions and partly to abstraction behaviour, including borehole depth and typical borehole pumping rates by farmers. Most groundwater abstraction is from <30m, and although abstraction has increased significantly over past decades, it does not currently exceed long term recharge rates, as evidenced by available groundwater level data.

References:
Lapworth et al. 2015. https://doi.org/10.1002/2015GL065798
MacDonald et al. 2016. https://doi.org/10.1038/ngeo2791

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**Session Classification**: Poster with refreshments

**Track Classification**: Topic 1 - Groundwater assessment and management
Evaluation of sustainable groundwater of the Mexico Basin aquifer after a century of intense pumping

Monday, 23 September 2019 18:00 (15)

The Mexico Basin (MB) includes the nation’s capital Mexico City, and is one of the most important metropolitan areas in the country representing the largest urban area in North America and the fifth largest in the world. A population currently reaching 22 million with constantly increasing water demands has resulted in the overexploitation of groundwater resources in the basin with changes in hydrological conditions over centuries. The urban, agriculture and industry practices on this area heavily rely on the basin’s aquifer groundwater resources to meet water demands; forecasts of expanding the metropolitan area will result in continued groundwater use with additional overexploitation. Historic and recent groundwater pumping has caused decrease in groundwater storage, significant declining groundwater levels, accelerating aquitard compaction translated in land subsidence, which is by now mostly permanent. The subsidence of the land has caused operational, maintenance, and construction-design problems for water delivery and flood control. Additional problems, which must be considered and monitored, are the changes in groundwater quality. Management and evaluation of this precious resource requires a detailed understanding of the aquifer dynamics along and within its natural boundaries. An integrated conceptual model of the Mexico Basin Aquifer (MBA) was developed for the first time based on literature, three-dimensional geologic and hydrogeological models, processes of hydro-mechanical behavior and geochemistry. This conceptual model updates and improves an existing numerical model, which is used as a guide to assessing the current and historical aquifer behavior and to provide aquifer sustainable evaluation through indicators. The model proposed in this study could be use in the evaluation of management plans designed to mitigate adverse impacts due to regional subsidence while also optimizing groundwater demands. This knowledge is critical to understanding the long-term sustainability of this resource under future land use and population growth in the MB. This work attempts to address the following issues and questions: What is the state of groundwater conditions in Mexico City after 100 years of increased pumping? What is the status of ground deformation (subsidence)? Is current groundwater use sustainable? What are the lessons learned and what is next?

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Session Classification: Parallel

Track Classification: Topic 1 - Groundwater assessment and management
The impact of land use cover change (1988-2018) on aquifer recharge capacity across Bogota river basin, Colombia

Monday, 23 September 2019 16:00 (60)

Groundwater represents an important natural resource that must be managed in an adequate manner for its sustainable continuous use. The Teusacá River, tributary of the Bogotá River, is located in an area with aquifers of primary and secondary porosity. They represent an important water supply for municipalities of La Calera, Guasca, Sopó and Bogotá, the Colombian capital. The recharges of these reservoirs are vital for the preservation of their service, and the land use and cover change (LUCC) could be the most impacting factor to infiltration and runoff. This study has the objective of quantifying the impact of the LUCC between 1988 and 2018 in the groundwater recharge of the Teusacá catchment, heavily impacted by urbanization, deforestation and proliferation of weekend leisure ranches. To accomplish the abovementioned, we estimate the loss of recharge volume through a GIS based model that integrates physical variables that influence the runoff rate and a 30 year time series of river flow, precipitation and air temperature to obtain a groundwater recharge map. Additionally, a statistical analysis of the time series of the flow water and precipitation was performed to detect any inset trends on the river flow throughout the 30 year period. First, a land use map is obtained for 1988 and for 2018. Subsequently, the maps of soil permeability, infiltration capacity and slope of the land are combined in order to produce a final potential percolation map corresponding to each year. Next, a water balance calculated using the 30 year time series to find the approximate percolation annual volumes, and finally, these values are associated with their respective spatial locations using the potential percolation map. The statistical analysis includes Mann-Kendall nonparametric test to detect trends in the historical data and analysis of hydrographs. The results show a significant loss of Paramo ecosystem and an increase of the urban/bare soil, crops and greenhouses area. The loss of covers with high infiltration rate lead to an annual decrease of approximately 8.5% of total the volume infiltrated in 1988. The statistical analysis of the shows a positive trend (p-value < 0.0001) of the surface runoff across the 30 year period, whereas the hydrographs, for similar volumes of precipitation, also shows drastic increases in the river flow volume for each precipitation event.

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Session Classification : Poster with refreshments

Track Classification : Topic 1 - Groundwater assessment and management
Numerical Simulation of Aquifer Responses to the Recharge Changes and Pumping Stress: The case of Modjo River Catchment, Central Ethiopia

Investigation of the aquifer responses to the recharge changes and pumping stress provides basic information for water resource protection, management, and development. In this study, steady-state groundwater flow model was constructed and calibrated to simulate groundwater flow system and evaluate response of the aquifer under increasing groundwater withdrawals and changes in recharge pattern. Changes in groundwater levels and budget under scenario of increase in groundwater withdrawals and decrease in recharge were evaluated using groundwater levels and fluxes under calibrated steady-state as a base line. The result of steady-state model shows that, the direction of groundwater flow is from the North (highland area) to the south (rift floor) and coincides with the direction of stream flow in the study area. The water budget under steady-state shows that the main inflow to the aquifer comes from rainfall, crater lakes and river, whereas outflow from the aquifer system are through groundwater abstractions, subsurface outflow and discharge to the crater lakes and river in the catchment. Scenario analysis shows that increase in groundwater withdrawal reduces groundwater discharges into the crater lakes and river and subsurface flow to the downstream. A decrease in groundwater recharge in the study area is also reduces groundwater discharges into the crater lakes and river and subsurface flow to the downstream area. In conclusion, increase in groundwater withdrawal and decrease in recharge in the study area will have a negative impact on surface water, groundwater quality and causes an environmental problem in general.

Keywords: Groundwater flow modeling, MODFLOW, Modjo River catchment, Upper Awash

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Session Classification: Poster with refreshments

Track Classification: Topic 5 - Tools, methods and models to study groundwater
A machine learning approach for imputation and spatial estimation of groundwater properties across the Middle Magdalena River Valley, Colombia

Thursday, 26 September 2019 16:00 (60)

The Magdalena River Basin covers a quarter of Colombia’s territory and contains 80% of its population. The middle sections of the Magdalena River hold significant volumes of nonconventional gas deposits which exploration is already ongoing. The social-economical relevance of this river makes imperative studies to describe the groundwater systems across this region. One of the main challenges to carry out such studies is availability of data characterizing the groundwater, which is frequently incomplete or inconsistent, in most cases due to budgetary limitations. Most parametric statistical methods, such as analysis of variance, cluster analysis and principal component analysis requires a complete data matrix to calculate multivariate metrics, like the covariance matrix. An alternative to deal with sparseness are imputation methods, statistical and mathematical approaches that estimate missing values in datasets based on a combination of the available data; these methods however are still essentially linear approaches. The self-organizing map (SOM) is an unsupervised vector-quantization technique that can be used to estimate missing values. The SOM can characterize high dimensional data sets, representing them in two or three dimensions projected onto maps composed by code vectors. Each code vector has the same dimension as the input data array. In this work we employ the SOM to estimate groundwater parameters across the Middle Magdalena Valley Aquifer System. The dataset was provided by the National Authority of Environmental Licenses and is composed of 289 wells with 13 hydrogeochemical variables (Total dissolved solids, electrical conductivity, Potassium, Bicarbonates, Depth, Nitrates, Magnesium, Temperature, Calcium, Chloride, pH, Sodium and Sulfates). A geostatistical analysis was performed, consisting of calculation of semivariograms to evaluate spatial continuity and for uncertainty analysis through Sequential Gaussian simulation and cross-validation. Model predictions were evaluated through a Bootstrap approach. A new SOM is created up to 30 times for each evaluated value, the parameters derived from the bootstrapping form the basis for a stochastic framework from which residuals are used to evaluate error statistics and model bias. K-means clustering, Ionic balance and Pipper diagrams were used to evaluate the main water groups after the estimation of missing samples.

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Session Classification : Poster with refreshments

Track Classification : Topic 9 - Groundwater and socio-economic development in Latin-America
Surface water and groundwater interaction in crystalline aquifer: an example from Itu (São Paulo, Brazil)

Monday, 23 September 2019 16:00 (60)

In São Paulo State the crystalline aquifer system occupies an area of approximately 62,000 km² (~25% of the state area). Despite of low productivity and highly heterogeneous aquifer, the increasing water demand in the metropolitan areas has intensified crystalline aquifer exploitation. Typically, high productivity wells are related to thicker weathered profile and occurrence of expressive discontinuities, concentrating wellbore perforation along the lineaments as well as valley positions. However, many studies recognize poor relationship between well productivity and its geomorphological position suggesting other constraints control well productivity. Aiming to better understand the constraints and groundwater dynamics in crystalline aquifers, this work developed a numerical groundwater flow model to evaluate a conceptual model of a production well based on geological survey, structural data, electrical resistivity imaging, pumping test and stable isotope analysis. The study area encompasses a well field catchment located in the municipality of Itu (São Paulo, Brazil). The crystalline aquifer system is composed of phyllite and quartzite of the Neoproterozoic São Roque Group. The conceptual model assumes a set of subvertical discontinuities, responsible for a hydraulic connection between surface water and well, and four layers representing the weathered profile described in the study area. Constant head boundary conditions were associated to the rivers and reservoirs, which are connected to the well by a discrete feature representing the fracture sets. The model was calibrated by pumping test drawdown data providing hydraulic conductivity values from 1x10⁻⁹ m/s to 3.24x10⁻⁴ m/s. The numerical simulation estimated a production of 12.6% surface water after 1440 minutes of continuous pumping, corroborating the water mixture inferred from isotope analysis. The results show that recharge and well productivity are related to connectivity of crystalline aquifer with surface water, as well as the extent of the weathered zone. The constant renewal of groundwater and its interaction with surface water ensure the sustainable groundwater usage for the municipal water supply.
The influence of snow storage and melting processes on the infiltration and recharge of aquifers has been little studied. In cooperation with some Spanish Confederaciones Hidrográficas, major governance organism within Spanish river basins, the UPM Department of Morphology and Terrain Engineering has designed a first experience on improving River Management related to recharge through melting processes. Results indicate that, under certain conditions, the formation of the snow mantle on high permeability lands and its subsequent liquefaction, increase the percentage of infiltrated water and the volume of water underground finally recharged. The peculiar hydrological characteristics of most of the Iberian Peninsule mean that the flow of low water at a certain point of the river network, is primarily due to the underground runoff from the depletion of the Masses of Groundwater (MASb) that drain upstream. These are sensitive to changes in the amount and distribution of snow in the headwaters of rivers. On this basis, the work proposes a methodological study of the influence of snow on the recharge within the ASTER model. At the same time, it carries out a study of the regional piezometric level of the Alto Tajo region and its relationship with the natural discharge of water bodies, which are largely natural, and the contribution to the Entrepeñas and Buendía reservoirs in the months of low water. The objective is twofold: 1) To be able to establish a quantification of the recharge caused by snow melting and 2) To relate the level of the piezometers with the dynamic reserves in the aquifer. Thus, the work addresses a systematic collection and study of the readings of piezometers currently installed, the contributions to the aforementioned reservoirs and the calculation of the balances for different situations of snow and precipitation modeled with ASTER. From these data and relationships, interesting conclusions will be obtained for the exploitation of mentioned basin.
CONDITIONS FOR THE FORMATION OF RADIOACTIVE CONTAMINATION OF GROUNDWATERS OF THE CHORNOBYL NUCLEAR POWER PLANT

This article presents new methods of forming high migratory ability of 90Sr in the underground waters near the 4th Unit of the Chornobyl NPP. Series of long time observations of 90Sr, its concentration, chemical composition and pH value in groundwater revealed the following patterns:
- at pH 7.5 - 8.5, concentration of 90Sr are dozens of Bq/l;
- at pH 8.5 - 9.5, concentration of 90Sr decrease to Bq/l units, due to the formation of a sparingly soluble strontium compound with carbonates;
- at pH > 9.5, concentration of 90Sr increase to values of 500-700 Bq/l.
According to the research of the phase differentiation, soluble fraction of 90Sr is growing from 50% to 98% of total activity of 90Sr.
At pH values higher than 9.5 90Sr forms complex compounds, which have high migration properties.
High pH values are formed by contacting infiltration and groundwater with concrete of buildings. In case of pH of groundwater increase to a value of 9.5 - 10, due to the corrosion of the concrete base of NSC, that overlaps the part of the aquifer, a significant increase in volumetric activity of 90Sr is possible.

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Session Classification : Poster with refreshments
Track Classification : Topic 8 - Groundwater quality and pollution processes
Falaj Modelling by Aquifer – Pipe Flow Coupling

Monday, 23 September 2019 16:00 (60)

The Falaj system is an ancient water supply and distribution system used in several countries ranging from Morocco in the West to China in the East. While they are also discussed under the Persian name ‘quanat’, we are using the Arabic term, as our study site lies in Oman. The so called Daoudi Falaj collect groundwater, which is then channelled to places of consumption, mostly for irrigation within oases and plantations. There are more than 3000 Falaj still in operation alone in Oman, which are understood as a technique for sustainable use of water under semi-arid or arid conditions. Nowadays Falaj are under decline not only to the advent of additional sources (desalination), but also due to decline of groundwater discharge and of contamination.

Falaj Daris near the city of Nizwa, located inland Oman, belongs to one of five Omani Falaj that were inscribed by UNESCO on the World Heritage list in 2009. The total length of three channels amounts to about 8 km, delivering a discharge of up to 2000 l/s. The channels are connected to a clastic aquifer, located between the Hajar mountains in the North and ophiolite rocks in the South. The clastic aquifer has an extension of 6.5 km2.

For modelling of the Falaj we couple a 2D horizontal groundwater flow model with flow simulation of the network of 1D pipes. To our knowledge this is the first hydraulic model of an Falaj and its connected aquifer. It is set up by the COMSOL Multiphysics software and calibrated for aquifer transmissivities and inflow rates from the adjacent mountainous regions. We utilize groundwater and Falaj discharge measurements obtained from the Ministry of Regional Municipalities and Water Resources (MRMWR).

We present the model and its results. It is intended to include further data from observation campaigns. In a further step it is planned to extend the flow model by a transport simulation, which can be a useful tool to predict the spreading of contaminations.

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Session Classification : Poster with refreshments

Track Classification : Topic 5.3 - Advanced modelling tools for subsurface hydrology: from the vadose zone to deep environments
Hydrochemical approach on Fluoride Water Pollution in Mt. Meru Watershed, Tanzania

Tuesday, 24 September 2019 16:00 (60)

High fluoride groundwater appears with alkali volcanic activity along Great Lift Valley in east Africa. Tanzanian people in Great Lift Valley are also suffering drinking water including high fluoride (> 1.5 mgF/L of WHO). We investigated the groundwater and river water fluoride pollutions in Arusha area of Mt. Meru watershed and Moshi area of Mt. Kilimanjaro watershed in May, September, 2018 and March, 2019 to provide the solutions to this issues as No. 6 of SDGs. We find some results below: 1) Water fluoride boundary is appeared between Mt. Meru (4.0 mgF/L in average) and Mt. Kilimanjaro (0.5 mgF/L in average) watersheds. 2) Waters with high fluoride show Na-HCO3 type water, and fluoride increase with Na. 3) Groundwater fluoride tends to be increasing with residence time and depth of well, but in recent twenty five years, fluoride is higher in younger groundwater. 4) Well waters supplied to Arusha city come from the source recharge zone of 2,000 m to 3,000 m in altitude of Mt. Meru, and the fluoride content tend to increase with the recharge altitude.

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Presenter(s) : Prof. NAKAYA, Shinji (Shinshu University, Japan)

Session Classification : Poster with refreshments

Track Classification : Topic 8 - Groundwater quality and pollution processes
Vegetation filters to attenuate Contaminants of Emerging Concern and to recharge the underlying aquifer.

Tuesday, 24 September 2019 16:00 (60)

A Vegetation Filter (VF), a type of Land Application System, is a non-conventional water treatment technology where wastewater and/or treated water is applied for the irrigation of a forestry plantation.

The aims of this study are i) quantify the removal capacity of one VF in terms of Contaminants of Emerging Concern (CECs) and ii) assess the capacity of VFs to increase groundwater resources.

For this purpose, two VFs of 56 m² with a planting density of 10,000 plants/ha of Populus x euramericanana (clone I214) were installed in an experimental plot at IMDEA Water Institute (Alcalá de Henares, Madrid) in 2016.

The impact of both filters in its underlying groundwater after three years of operation has been evaluated, paying attention to the influence of the VF on groundwater recharge and dynamics, based on piezometric level measurements and hydric balance calculus. To assess the infiltrating water quality, the study shows the results of two years of water monitoring in different control points: wastewater influent, infiltrating water below one of the VFs and groundwater.

The obtained results indicate that the constant operation of the VFs has contributed to recharge the underlying aquifer. Both, local piezometry and underground flow have been modified due to the water infiltration from the VFs.

Regarding the infiltrating water quality, there is an attenuation of CECs, especially in the first few centimetres of soil, due to sorption and biodegradation processes. Thus, groundwater analysis show that both concentrations and detection frequency of these contaminants greatly decreases in the aquifer.

To enhance these results, woodchips have been added to soil in VFs. This amendment has the advantage of being provided from the IVF itself following therefore a sustainable and resource recovery approach. We expect that woodchips increase sorption sites and stimulate microbial activity.

This study belongs to the project "FILVER+: Water reclamation by using a new concept of land application systems", with the reference CTM2016-79211-C2 (AEI/FEDER, EU), and it is part of the 2016 call for R+D+i projects of the Spanish Ministry of Economy, Industry and Competitiveness.

Keywords: Reclaim, Recharge, Contaminants of Emerging Concern, Vegetation filters.

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Session Classification : Poster with refreshments
Track Classification : Topic 8 - Groundwater quality and pollution processes
Hydrochemical characterization of a nitrates polluted aquifer to test a treatment with biological-base to produce drinking water (LIFE ECOGRANULARWATER project)

Monday, 23 September 2019 16:00 (60)

The objective of LIFE ECOGRANULARWATER project is to demonstrate a new treatment system, low-cost and environmentally friendly, based on biological methods and powered by solar energy, for the purification of groundwater, polluted by nitrates, intended for human consumption. With this aim, the installation of a full-scale plant in Torre-Cardela (760 inhabitants; Granada, Spain) has been carried out, where high nitrates contents have been reported from the 1990s. It is expected that the new plant will achieve the same results (water suitable for human consumption) but with an improved cost-effectiveness ratio in the production process than the current treatment (reverse osmosis).

The study of groundwater characteristics is essential, in order to improve the efficiency of the new treatment proposed. For this reason, a comprehensive characterization of the aquifer (Calcarenitas de Torrecardela, ES050MSBT000054106) that supply the municipality has been carried out, through reliable groundwater sampling campaigns.

Main lithologies present on the studied groundwater body are calcarenites, bioclasts sandstones and marls, Eocene-Oligocene, affected by faulting and bending. The resulting aquifer is fissured-karstic, classified as moderate productivity and with a good global status (Hydrological Basin Plan of the Guadalquivir river basin).

Sampling campaigns were carried out from February to December (2018). Water samples were collected from springs, supply wells and boreholes, on which pesticides, predominant cations and anions, and nitrates have been analysed.

Interpretation of the hydrochemical data results indicated that the main hydrochemical facies was calcium-bicarbonate and nitrates concentration varied on those months between 0.4-105 mg/L, although on samples from the main supply well ranged between 23-84 mg/L. Regarding the content of pesticides, only two substances were detected above 0.100 μg/L (diphenylamine and fluazifop) at two different sampling points (springs). In general, the load of organic pollutants was low (from 0.072 to 0.474 μg/L).

Higher nitrates contents have been detected after rainfall events that took place after olive trees crops fertilization periods (main economic activity of area inhabitants). Therefore, fluctuations were consequence of the combination of crops fertilization cycles and rainfall events, that allowed the percolation of the nitrogen excess accumulated in the soil to the water table.

In conclusion, it is essential to anticipate these nitrates concentration variations in order to adapt the operational tasks of the full-scale plant to improve the bioreactor working and produce water suitable for human. For this reason, nitrate contents in raw water will be monitored in the facility itself, in order to adjust the cycles/turnover time of treatment depending on nitrates contents. These biological analyses are in progress. At the end of this part, the project purpose will be reached, a replicable and low-cost drinking water treatment, affordable for small communities, and with easy operating and maintenance tasks.
Hydrochemical characterization of...
Global air-temperature changes over the last 150 years and in particular during the last 30 – 40 years are well documented world-wide. In alpine areas in Europe the increase in air-temperature is even higher in the range of 2° C. Very few studies exist about groundwater temperature changes due to global warming. The increase or decrease in temperature at the point of discharge depends besides the air temperature at the time of infiltration on the amount of precipitation, the local meteorological conditions, the mean residence time, the land use, and the natural and anthropogenic heat flow during the passage underground.

Nearly no papers exist about the water quality changes due to global change impacts. This is very difficult to evaluate due to missing long-term quality measurements and strong impacts by anthropogenic activities and land use changes. To avoid the complication by anthropogenic land use changes and activities the authors investigated the on-line discharge, temperature, and electric conductivity measurements as well as quarterly hydro-chemical analyses of 38 Alpine springs from a monitoring network all over the Austrian Alps (approx. 60,000 km2). All the selected springs have a recharge area with no or minimal anthropogenic impacts during the last 30 – 40 years. About 235,000 on-line measurements and 11,000 chemical analyses were evaluated for trends and compared to daily measurements at meteorological and surface water stations close to the recharge areas of the springs. To show the connection to the paleoclimatology changes of existing δ18O measurements on precipitation and spring water was evaluated as well indicating altitudes of recharge areas in range of 500 – 2400m.

Thirty-eight springs with a minimum record of 16 years have been selected for trend analysis over a period of 20 years (1993 – 2013). 28 (74%) of the selected spring show a significant mean increase in water temperature of 0.34 °C in the range of 0.06 to 1.03 °C. This increase is half of the air- and water temperature increase in meteorological stations and surface waters close to the recharge areas of the investigated springs. The electric conductivity linearly increased in 21 (55%) of the investigated springs at about 4%. The discharge stayed the same in most springs. In 23 (72%) springs the content of dissolved oxygen decreased over these 20 years at about 9% percent.

The reasons of the changes in water-temperature, dissolved load and the oxygen content as well as potential water quality changes will be discussed and interpreted.

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**Session Classification**: Poster with refreshments

**Track Classification**: Topic 2 - Groundwater and climate change
Multi-isotope-measurements (18O/2H,3H/3He,13C/14C) confirm old ascending karst spring-water at the western border of the Pannonian Basin (Austria).

The Winden Springs and two drilled extraction wells are situated at the North-East slope of the Leitha Mountains. They are a small mountain range (max. 484 m) extending 30 km in the SW-NE direction at the West-side of the Lake Neusiedl. The region is characterised by major SW-NE trending fault zones forming the Western margin of the Pannonian Basin (Austrian-Hungarian border). The Winden Springs are used as drinking water source from the regional water supplier (Wasserleitungsvorstand Nördliches Burgenland). The Winden Spring discharge is 13 L/s and the two additional extraction wells deliver additional 20 L/s. All the waters are from the alkaline-earth-carbonate – sulphate type with an electric conductivity of 700–1000 µS/cm and a mean water temperature of 13 ºC. All three water extraction sites are in the area of a major fault zone parallel to the Leitha Mountains. The core of the Leitha Mountain range is formed by Variscian mica-schists and paragneiss. They are overlain by Triassic dolomites and Tertiary Leitha-Limestones. In a recently drilled exploration-hole the tectonically deformed dolomite was recorded down to 150m depth. From the results of the multi-isotope-investigations (δ¹⁸O,2H, 3H/3He, 13C und 14C) on all three water-extraction points during May – June 2017 in combination with basic hydrogeological investigations following conclusions can be drawn:

- The spring and the well waters are a mixture of newly formed groundwater and on the fracture-zone ascending old water. This is supported by high helium-4 concentrations, the low radiocarbon(14C)-values and the slightly elevated groundwater temperature of 13-14 ºC.
- Depending on the estimated end-members a portion of 10 to 50 % of old ascending waters can be calculated.
- Based on the radiocarbon(14C)-values of the sulphate – rich ascending waters a mean transfer time (MTT) of 10,000-15,000 years can be calculated. This agrees with relatively depleted δ¹⁸O-values of -12 bis -11.5 ‰, which indicates recharge during colder climates.
- The estimate of the MTT of the "young" water fraction is complicated by high 3He/4He-ratios, which indicate a mantle helium contribution. Tritium-measurements allow an estimated time range of 10 to 40 years.
- The "young" water fraction is characterised by high nitrate concentrations, which originate from vineyard fertilisation. The low yearly precipitation rates (400-600 mm) limit the dilution of the nitrate concentrations.
- In the Winden Spring and the shallow extraction wells (< 30m) groundwater is naturally mixed, which allows the compliance with the nitrate and sulphate drinking water limits.

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Session Classification: Poster with refreshments

Track Classification: Topic 7 - Karst Hydrogeology
HOW DOES THE DISSOLUTION KINETICS AFFECT THE EVOLUTION OF THE SOLUTION PIPES?

Dissolution by a reactive flow is a complex phenomenon influenced by a number of different parameters, including flow rate, diffusion rate of the reactant, reaction rate and the pore space characteristics of the host rock. Depending on the values of these parameters, the dissolution patterns will have different morphological features. In particular, there is range of parameters where the dissolution front becomes unstable, which is accompanied by a formation of pronounced dissolution channels, which are called solution pipes in geological literature and wormholes in the petroleum industry, where they are produced to stimulate the flow from oil reservoirs. In the natural settings, these features are formed in rocks with a very high porosity and then with a rather large flow rate. Their shapes are strongly related to their characteristic sizes. At the macroscale (1-10 metres) they are usually almost cylindrical with a diameter from a few cm up to a meter, while at microscale they show a highly ramified, fractal-like shape. To investigate this variability and to understand their formation and evolution, we are conducting microfluidic experiments using a self-constructed microfluidic cell. We are using a system consisting of two polycarbonate chips in which it is possible to have a control on flow rate and on the aperture. The lower plate has an indentation that can be filled with gypsum, while on the upper chip there is a reservoir that allows water to be supplied to the system in a controlled way. We are using powder gypsum during these experiments because it has a very simple chemistry, high solubility in water and therefore allows a greater speed of dissolution. The two chips are joined together with an ultrathin, double coated tape of variable thickness that allows us to control the aperture of the system, which can thus be regarded as an analog fracture. As the gypsum chip is dissolved, we observe the appearance of fingers of different shapes and densities, depending on the flow rate and the aperture. We report the results of these experiments and relate the observed features with the natural shapes found in the epikarst systems.

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Session Classification : Poster with refreshments
Track Classification : Topic 7 - Karst Hydrogeology
The GAS is recognized as one of the most important transboundary regional aquifer in the world. Its aquifer potential to supply large amounts of water for domestic, agriculture and industrial use is well known and serves as a key motivation factor to understand its circulation model. The GAS is considered to be storage dependent where annual extraction estimates are higher than recharge, a fact that should constrain GAS management strategies. It is described as a thick package of clastic detrital sedimentary sequences, whose geometry and structural framework is controlled by large structural features, mainly arcs and fault zones. The GAS hydrogeological knowledge has evolved from a large homogeneous groundwater structure to a more complex and heterogeneous system. Studies dealing with isotopic data have evolved from local to regional sampling campaigns to better define the flow circulation model. One of the most important findings from these assessments dealt with isotope coherence against the hydrochemical evolution along flow lines, from well-known GAS recharge areas in the eastern border towards the deeper confined parts at the western side. 14C age estimates, close to 40,000 years, were used to calculate mean velocities (2.6x10^-5 m/s), which seemed to be coherent to GAS hydraulic parameters and aquifer geometry (between 2.4x10^-6 and 4.5x10^-5 m/s). Age interpretations in few samples using U isotopes, followed by 36Cl age estimations suggested residence times about 600,000 years or greater. It has turned out clearly that previous 14C age estimates for the confined GAS were not correct and new approaches based on cosmogenic radionuclides were needed. Recent research efforts have been focused in the northern part of the GAS and new samples from deep confined wells were collected according to the multi-tracer approaches. Representative deep GAS wells were sampled for 81Kr, 4He, stable isotopes and 14C. Results have shown residence times varying from modern water up to about 834 +/- 91ka, based on 81Kr. 4He concentrations were three times higher than those at the recharge areas considered to be in equilibrium with atmospheric He. Ne/He and 3He/4He rates indicated that the He built in the GAS is a mixture of atmospheric and crustal origin and that the mantle contribution of He is considered negligible. Thus, 81Kr ages were used to calibrate the 4He geochronometer. Noble gas results from the field campaigns carried out after 2015 covering the whole GAS system are being analyzed. Present on-going research is aimed at finding a convergence between hydraulic modeling, GAS hydrochemistry evolution and groundwater age estimates based on multi-tracer approaches. As soon as 81Kr and 4He age results and noble gases recharge paleotemperatures are delivered, more enhanced and complete conceptual models are going to be necessary to cope with the new findings.

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Session Classification : Poster with refreshments
**Track Classification** : Topic 5.4 - Innovative approaches for understanding groundwater flow systems
Spatial and Temporal Mapping of Surface and Groundwater Stable Isotopes Enable Insights into Hydrologic Processes at the Catchment Scale

Isotopic analyses of $\delta^{18}O$ and $\delta^2H$ of water through the hydrologic cycle have allowed hydrologists to better understand the portioning of water between the different components. Isoscapes on a large spatial scale have been created to show isotopic variation in waters as a function of elevation, temperature, distance to coast and water vapor source. Though this has not been done on a 10,000 sq mi area, sub-regional scale or for that matter exhaustively sampling the important components of the terrestrial hydrologic cycle (groundwater, surface water and soil waters). We present the spatial and temporal isotopic results of precipitation, surface water, and groundwater of an ongoing study across Massachusetts, USA in order to establish an isotopic baseline and isoscape for the region. The isotopic signature of $\delta^{18}O$ and $\delta^2H$ of the samples are measured by a wavelength scanned cavity ring-down spectrometry on un-acidified water samples by a Picarro Cavity Ring Down Spectrometer (L2120-I) analyzer. Our current database consists of water samples from 14 precipitation sites, 409 ground water sites and 516 surface water sites from the three climate zones of Massachusetts as determined by the National Climate Division Center. Our results show that groundwater ranges from $\delta^{18}O$ -11 to -1 ‰ surface water ranges from $\delta^{18}O$ -13 to -3.84 ‰ and precipitation ranges from $\delta^{18}O$ -17.88 to -2.89 ‰. On a first order, timing of groundwater recharge and surface water storage effects the isotopic composition of precipitation surface and groundwater. Though, on a second order, elevation and geographic location affect the isotopic composition of precipitation, groundwater and surface water. Our results indicate that for precipitation, surface water and groundwater the mean $\delta^{18}O$ are more enriched in climate zone 3, which encompasses areas near the coast, than climate zone 1 and 2 which encompasses the western and central portion respectively. Within Massachusetts the isotopic composition of groundwater in till, glacial fluvial and bedrock aquifers are distinct which indicates the potential for surface and groundwater interaction. This dataset will become an important tool for water management and water resources.

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**Session Classification**: Poster with refreshments

**Track Classification**: Topic 2 - Groundwater and climate change
Challenges in groundwater management in a costal semiarid basin in Ecuador

Thursday, 26 September 2019 16:00 (60)

The objective of the study is to review, evaluate the groundwater management practices in the semiarid coastal Zapotal watershed (574 km2) in Southwestern Santa Elena Province, Ecuador. Due to saline aquifers, the low precipitation, and high evaporation, and resulting water scarcity, fresh groundwater is present only in few areas in Santa Elena. Traditionally, groundwater from Zapotal catchment has been providing drinking water for the local communities and their surroundings in Santa Elena Province. Although these communities (41217 Zapotal inhabitants) are nowadays dominantly served by surface water from an irrigation channels network "Chongón-San Vicente trasvase", the groundwater resources remains fundamental because of frequent surface water shortage. Communities with access to fresh groundwater (i.e., Pechiche and Rio Verde) often used it as economic income source, selling the groundwater to individual farmers and inhabitants without access to freshwater. The groundwater is distributed to the population in two ways: a) traditional private or community wells and b) water tanks providing paid groundwater. The presentation addresses the following crucial groundwater challenges in Zapotal. Firstly, there is a need to assess the water balance based on representative and long-term data, such as: climate, hydrology, hydrochemistry and water levels. The lack of monitoring programs at local and regional levels restrains the knowledge of recharge mechanisms. The experience from Ecuador indicates that the limited data availability as well as the restricted access difficult data acquisition might be a common problem across Latin-America. We are in the process of the developing of a network that would consist of monitoring water level in four wells in the Pechiche community. Secondly, there is a need to conjoint watershed-based management, that also includes surface-groundwater quantity and quality interactions across the whole catchment. The current management practices are focused on the need of individual users instead of considering environmental implications at the basin scale context. Besides the influence of marine water intrusion caused by the over pumping of coastal aquifers, the Zapotal basin and its surroundings may face the interaction of saline waters from the shrimp pools with local fresh waters. It is suggested to address this effect integrated in the future coastal groundwater management. Thirdly, different hydrogeological conditions required groundwater management practices. In the Zapotal catchment, two subbasins appear: the saline Zapotal basin, and the relative freshwater of Rio Verde watershed. It is suggested the communities in the Rio Verde watershed maintained a collaborative control of potential contamination and other shortages of this valuable resource.

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Session Classification : Poster with refreshments

Track Classification : Topic 9 - Groundwater and socio-economic development in Latin-
America
Relevant hydrogeological processes for integrated hydrological models in tile-drained agricultural fields

Thursday, 26 September 2019 16:00 (60)

Subsurface drains are used worldwide to control the water table levels and improve soil conditions for agriculture. However, tile-drains fasten N load to surface water before nitrate reduction occurs increasing water contamination. In Denmark, new regulation strategies have been studied to reduce nitrate leaching from agriculture. However, estimations of the amount of water flowing through tile drains must be more precise to identify the fields where the N fertilizer application most contributes to the nitrate load to the surface water bodies. The purpose of this research is to evaluate different modeling settings to improve and simplify surface water and groundwater flow simulations in tile-drained fields, which is the basis for nitrate transport models. The physically-based HydroGeoSphere numerical model has been used for 3D fully-integrated modeling in a small tile-drained area (11 ha). The seepage nodes approach applied in homogeneous soil layers was suitable and faster than the others to simulate surface and groundwater flow. However, when 1D lines were included in the model to represent tile-drains, low flow and cumulative discharges showed better agreement with observed data. Although including macropores in the model improves the representation of peaks and low flow, the simulation times and data requirement limit the macroporosity representation at catchment-scale. Once the soil clayey zones are included in the model the surface flow increases resulting in less water available for drainage discharge. However, the water table levels in the heterogeneous soil model were better represented. This study highlights modeling features expected to simplify and increase the accuracy of hydrological modeling in humid agricultural areas to support legislative demands that water-regulatory agencies might use for water management.

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Session Classification: Poster with refreshments

Track Classification: Topic 5.4 - Innovative approaches for understanding groundwater flow systems
Hard-rock groundwater potential assessment in the Aji-Chay basin, West of Iran’s drying Lake Urmia

Monday, 23 September 2019 16:00 (60)

Lake Urmia, the largest in the Middle-East, is located in the northwest of Iran. The lake has been dramatically desiccating during the last two decades, mainly as a result of human-induced agricultural development, which remarkably accounted for diminishing of surface and subsurface inflows to the lake. This research focused on the mountainous area of Aji-Chay river basin, the largest basin supplying the lake, determining different groundwater potential zones, GWPZ, over the area. In order to indicate the zones, Multi Criteria Decision Making, MCDM, techniques in the frame of Geographical Information System, GIS, were utilized. Accordingly, GIS thematic layers of precipitation, lithology, landform, density of lineaments and faults, slope, land curvature, and stream density were quantified based on the direct field observations, geological maps and Remote Sensing. Among available MCDM techniques, Entropy, Analytical Hierarchy Process, and Fuzzy techniques were comparatively employed, utilizing spring and exploitation wells as validation tools. Results showed that, Entropy based MCDM techniques was slightly more accurate than the rests. Since impermeable intrusive and extrusive igneous rocks of low fracturing are abundantly cropped out over the area, the high and very high GWPZ were estimably negligible. The resultant map of GWPZ can be adopted to site any new exploitation water wells in the region, indeed. However, the prospective karst and hard-rock groundwater has to be considered as substitution of current drinking water supply of low quality in the villages and rural areas. Because, any further exploitation cannot be amenable for such a basin, feeding one of the most precious UNESCO Biosphere Reserve.

Keywords: karst and hard-rock groundwater potential zone, Entropy, Analytical Hierarchy Process, Fuzzy, Lake Urmia

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Session Classification: Poster with refreshments

Track Classification: Topic 1 - Groundwater assessment and management
Application of a flow-through cell to monitor groundwater source heat pump systems in Melhus, Norway

Friday, 27 September 2019 11:30 (15)

Groundwater in unconsolidated sediments represent a local and renewable energy resource. By use of a groundwater source heat pump system (open-loop system), 70% of the heating demand of buildings can be expected to be covered by “free” heat in the ground. The system also offers the possibility of cooling in warmer periods. Despite of this the method is still not much utilized in Norway, probably due to lack of knowledge about design, operation and maintenance of systems operating in challenging groundwater chemistry. Therefore, the research project ORMEL (Optimal utilization of groundwater for heating and cooling in Melhus and Elverum) was initiated in 2015 (until 2018). A sequel, ORMEL 2, followed from autumn 2018, with one of the R&D focuses being the challenging groundwater chemistry in Melhus.

Nine open-loop systems in the city centre of Melhus are extracting groundwater from a confined, anoxic aquifer with high concentrations of iron and manganese. In the open-loop system, iron and manganese is oxidized to form insoluble compounds incrusting well screens, pipes and heat exchangers. The incrustations are detected in all of the nine plants where they result in higher maintenance costs and lower energy savings for the systems. However, their genesis is still not fully uncovered, and may include oxygenation by air contact or mixing, bacteria, or CO2 degassing, possibly combined with mechanical incrustation. This hampers the selection of a proper remediation technique.

To investigate the groundwater chemistry and the cause of incrustations in the Melhus plants, a flow-through cell has been constructed. This is connected to the groundwater pipes through taps in the machinery rooms diverting water from the system through the cell. In the flow-through cell electric conductivity, dissolved oxygen, pH and redox potential is continuously monitored, thus facilitating easy, continuous measurement of time variations in the parameters without atmospheric interaction. In addition, field observations of bubbles, odors and sedimentation in the cell may be provide valuable information. Furthermore, shutting the valves and disconnecting the flow-through cell offers the possibility to investigate the kinetics and temperature dependence of CO2 degassing. Combining these field observations and data with alkalinity measurements and water samples analyzed for cations and anions, may uncover the redox processes and incrustation pathways in the open-loop systems.

In the presentation, results from flow-through cells measurements will be presented and analyzed. Also, alternative incrustation characterization approaches and possible remediation techniques will be discussed.
Track Classification: Topic 5 - Tools, methods and models to study groundwater
Hydrogeochemical evidences of multi-layered groundwater circulation and anthropogenic pollution in Atacama Desert Hillslopes (Oasis de Pica, Northern Chile)

Thursday, 26 September 2019 16:00 (60)

Pica Oasis is located in the Atacama Desert at 1400 m.a.s.l., in the most arid place in the world. A rate of 10 mm/year average rainfall below 2000 m.a.s.l. (Houston, 2002), and a high rate of evaporation (2000-3000 mm/year; DICTUC, 2007; Ortiz, 2008) trigger a precipitation deficit. In the area, surface waters are very variable over time, and the socioeconomic development of the commune of Pica depends mainly on groundwater resources (human consumption, agriculture, mining purposes, in addition thermal springs have a balneological use). However, the understanding of the functioning of the aquifer system is still unclear.

In this contribution, the geochemical and isotopic composition of groundwater is used to establish a conceptual model of the hydrogeological system of the Pica Oasis. During September 2016 and February 2017, 55 groundwater and rainwater samples were collected in the Pica and Altos de Pica areas. The electrical conductivity (EC) varies between 153 and 3990 µS/cm and the waters are Na-CI, Na- HCO3, SO4-Na, SO4-Ca and mixed-Na type. The high values of NO3 measured, up to 151 ppm, would evidence an anthropogenic (agricultural) contamination. The lithological and structural characteristics, represented on the surface by 3 NS flexures between Pica and Altos de Pica, make up the system that sustains the circulation of the groundwater of Pica.

The different geochemical and 13C analyses made possible to differentiate at least 3 circulation patterns governing the groundwater of the Pica Oasis: (i) deep and confined circulations in the alluvial layer deposited on the Mesozoic basement (facies Cl-Na, CE = 3120 µS/cm, T° = 32.5 ℃, δ13C = -12.9 ‰ (PDB) and NO3 ≈ 1.2), partially to completely disconnected from the surface; (ii) shallower and semi-confined circulations in the fractured ignimbrites (facies HCO3-Na, CE = 330 µS/cm, T° = 30.5 ℃, δ13C = 8.0 ‰ (PDB) and NO3 = 2.7) partially connected to the irrigation waters. Finally, iii) waters related to the shallowest circulation of the system, with major elements concentrations and δ13C values are between groups i and ii (facies SO4-Na, SO4-Ca and mixed-Na, CE = 1290 µS/cm, T = 27.2 ℃, δ13C = -10.6 ‰ (PDB) and NO3 between 0.2 – 151.0), and may be a consequence of mix between these end members (Gi and Gii). The highest nitrate concentrations are related by the agricultural activity of the Pica Oasis. Therefore, we interpreted that groundwater composition is due of both processes: Mixing and irrigation return.

The conceptual model of the Pica Oasis will improve the understanding of the hydrogeological system and will provide the base for the numerical model application facing of anthropic and climatic pressures.

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**Session Classification:** Poster with refreshments

**Track Classification:** Topic 9 - Groundwater and socio-economic development in Latin-America
A new inverse modelling algorithm for hydraulic tomography based on a mixture model

Monday, 23 September 2019 16:00 (60)

Hydraulic Tomography (HT) has become one of the most robust methods to characterize the heterogeneity in hydraulic parameters such as hydraulic conductivity and specific storage. However, in order to obtain high resolution hydraulic parameter estimates, several pumping/injection tests with sufficient monitoring densities are necessary. In highly heterogeneous media, even with large numbers of measurements, the resolution may not be sufficient for predicting contaminant transport behavior. In addition, during inverse modeling, the groundwater flow equation is solved numerous times, thus the computational burden could be large, especially for a large, three-dimensional, transient model.

In this work we present a new approach to model aquifer heterogeneity, based on a Gaussian Mixture Model (GMM) to parameterize the K field, which significantly reduces the number of parameters to be estimated during the inversion process. In addition, a new objective function based on the spatial derivatives of hydraulic heads is introduced. This objective function increases the sensitivity of the parameters and eliminates the skin effect.

The developed approach is tested with synthetic data and data from a previously conducted sandbox experiments. Results indicate that the new approach improves the accuracy of the K distribution produced through HT and reduces the computational effort. It also addresses the problems involved in the inverse problem due to including noisy data, the need for many pumping/injection tests and the lack of resolution when the K distribution does not have a Gaussian distribution. For two-dimensional synthetic experiments, this approach was able to achieve a significant reduction in the error for K field estimation as well as computational time compared to a geostatistical inversion approach. Similar results were also achieved when the approach was tested using pumping test data conducted in a synthetic aquifer constructed in the laboratory.

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Session Classification : Poster with refreshments

Track Classification : Topic 5.3 - Advanced modelling tools for subsurface hydrology: from the vadose zone to deep environments
Identifying interactions between river water and groundwater in the North China Plain using multiple tracers

Tuesday, 24 September 2019 16:00 (60)

Interactions between river water and groundwater have been used to help understand the movement of water and to evaluate water quality in the semi-arid area of the North China Plain (NCP). Stable isotopes, chlorofluorocarbons (CFCs) and hydrochemistry were used to study the influence of surface water from the Xiao River on regional groundwater. Using a mass balance approach based on chloride concentrations, hydrogen and oxygen isotope ratios, the average fraction of surface water recharging to groundwater was 50–60 %. CFC results indicated that the groundwater recharge age varied from 22.5 to 39.5 years. The vertical flow velocity of groundwater was estimated at about 1.8–3.5 m year⁻¹. Nitrate concentrations in groundwater varied from 9.42 to 156.62 mg L⁻¹, and exceeded 50 mg L⁻¹ in most aquifers shallower than 80 m bordering the Xiao River. The d15NNO3 data indicate that the major sources of nitrogen in groundwater are human sewage and animal excreta. Because groundwater is the main source of drinking water, there should be concern about public health related to the elevated nitrate concentrations in the NCP.

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Session Classification : Poster with refreshments

Track Classification : Topic 8 - Groundwater quality and pollution processes
Health risk assessment of groundwater nitrogen pollution and its uncertainty analysis in Songnen Plain.

Monday, 23 September 2019 16:00 (60)

Affected by human activities and agricultural development, the nitrogen content of groundwater in the Songnen Plain seriously exceeded the standard. To explore the status of nitrogen pollution and its effect on human health, this study employed shallow groundwater sampling test data, geostatistical analysis and conducted the triangular random model to assess the risk of nitrogen exposure in children and adults, and performed the uncertainty analysis. The results showed that:

1) The main nitrogen pollutants was nitrate nitrogen, and the sample exceeded the standard rate of 44.35%, and the maximum value reached 566.2 mg/l, and the region with a concentration of nitrate nitrogen greater than 20 mg/l accounts for about 60% of the total area in the region, mainly distributed in the high plain area of the eastern and central parts, and the western front slope plain is less polluted;
2) Based on the triangular fuzzy coupled stochastic model on the Isight5.9-2 platform, considering the impact of human activities and agricultural development, the study area is divided into different units. The analysis shows that the non-carcinogenic risk ranking is: evaluation unit III> evaluation unit II>evaluation unit I, and the contaminants in Unit III are mainly derived from agricultural activities, and the risks in Units III and II are much higher than the safety threshold value of 1, which may cause potential harm to children and adults, and threaten children more;
3) The uncertainty of pollutant concentration and parameters has a large fluctuation range for the risk value, and the triangular random model is more sensitive to data changes, which can reduce the uncertainty of the triangular fuzzy method. The unit I risk interval value crosses the safety threshold 1 ,and it may mislead pollution prevention and control decisions; the contribution rate of nitrate nitrogen concentration to risk is above 90%, which clarifies the necessity of random sampling, at the same time, the test error of nitrate nitrogen should be minimized and relevant data should be collected to improve the reliability of the evaluation results.

Key words: groundwater; nitrogen pollution; health risk assessment; uncertainty.

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Session Classification: Poster with refreshments

Track Classification: Topic 3 - Groundwater sustainability and governance
Vulnerability assessment and actual groundwater quality data - a case of study in Mozambique

Monday, 23 September 2019 16:00 (60)

The Nhartanda Valley is located in Southern Africa, center of Mozambique, in the southern part of the City of Tete. It occupies an area of 6.8 km². City of Tete faces a set of serious structural issues of access to water such as a precarious public water supply system - large losses, pressure drawdown, and lack of investment in the network management, water rationing and a poor sewerage system. Historically, the public water supply in the area relies mainly on surface water reservoirs and groundwater. Nevertheless, repeated droughts have caused groundwater abstraction increase in the last few decades, and it was identified as a risk for the groundwater quality and quantity. Furthermore, the presence of potential contaminant activities along the valley and adjacent areas associated with Zambezi river pollution contribute to the degradation of water quality. The analysis of hydrology, hydrogeology and land uses of the study area has been carried out. Groundwater vulnerability was determined through the calculation of the GOD index and DRASTIC index for wells and boreholes of the Nhartanda Valley. The vulnerability to water pollution of Nhartanda Valley, through the application of the GOD methodology, varies from medium to high. The 9.1% of the study area is considered of medium vulnerability, while 90.9% is of high vulnerability. Of the latter, 80% of the area has a moderately high vulnerability. The vulnerability of the aquifer, through the application of the DRASTIC methodology, varies from high to very high, corresponding to 40% and 60% of the area, respectively. The two methodologies have shown a similar vulnerability response of the aquifer, which is characterized by a high to very high vulnerability. On the other hand, the actual physico-chemical and microbiological water quality of the aquifer has been evaluated from the results of water samples analyses from the wells and boreholes of the valley. A specific set of actions and measures are necessary and urgent for the protection of Nhartanda Valley aquifer; which main function is to provide drinking water to City of Tete population. The identification of the most vulnerable areas has generated basic information to water use planning and designing of measures for aquifer protection and remediation.

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Session Classification: Poster with refreshments

Track Classification: Topic 1 - Groundwater assessment and management
The parametric uncertainty analysis of water and nitrogen transport simulation in vadose zone for irrigation districts in western Jilin province, China.

Tuesday, 24 September 2019 16:00 (60)

The saline soil area in western Jilin is affected by water conservancy projects and agricultural activities, the leaching loss of nitrogen is serious in the unsaturated zone of the irrigation area, causing groundwater pollution. The numerical simulation of soil water and nitrogen transport is an effective technical means to understand the process and mechanism of complex nitrogen infiltration at farmland scale. However, soil water and nitrogen transport parameters under farmland scale have strong spatial variability, which leads to random uncertainty of model parameters in the simulation calculation and prediction process. Therefore, this paper takes the unsaturated zone of the saline soil area in Da’an city as the research object, designs the field experiment, constructs an unsaturated zone of water and nitrogen transport model in Hydrus and verify it, considering soil spatial variability, based on the GLUE method, the uncertainty of the water and nitrogen transport reaction parameters of the model was identified, and predict the range of water and nitrogen parameters and its effect on the cumulative leaching amount of nitrate nitrogen were predicted under the uncertain parameters. The results are as follows: (1) The RMSE values of soil water content, nitrate nitrogen and ammonium nitrogen are all small, the n-RMSE values are in the acceptable range, and the index of coincidence (d) and correlation coefficient (R2) is close to 1, indicating that the simulation effect of the Hydrus model is better; (2) Soil saturated water content, dispersivity and adsorption coefficient have better identification, and the range of values is reduced to 0.42-0.45 cm3/cm3, 0.26-0.29 cm, and 0.141-0.158 L/mg, respectively, denitrification rate and saturated hydraulic conductivity have great influence on the uncertainty of model results; (3) Under different schemes, the predicted range of soil nitrate-nitrogen accumulation leaching from 0-100 cm is 10.34-13.63 kg/ha, 9.47-12.71 kg/ha, respectively, and the range of prediction interval can be narrowed considering the parameter uncertainty, it can reduce the uncertainty of the results, improve the simulation accuracy of water and nitrogen transport in the unsaturated zone, and increasing the result accuracy when quantitative assessment of cumulative nitrate leaching risk.

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Session Classification : Poster with refreshments

Track Classification : Topic 5 - Tools, methods and models to study groundwater
Study on the variation rules of soil-water characteristic curves under different conditions combining characteristics of compared model fitting parameters

Soil–water characteristic curve (SWCC) is an important unsaturated soil property relating the water content of a soil to soil suction, which is a major key in understanding and engineering relevant systems such as soil aquifer treatment and wastewater irrigation. It is one of the basic curves that can represent the soil hydraulic properties in a wide range of applications, and its accurate measurement and fitting are the basic conditions to numeralize the hydraulic properties of soil media in vadose zone. In this study, we measured SWCCs of different particle sizes pure sandy soils (low suction range suction) by sand-funnel method and sandy soils mixed with different biofilm analogue (xanthan) concentrations (high suction range) by centrifugation, respectively. The study showed the smaller the particle size and the more analogue (biological activity), the stronger the water holding capacity. Fitting and comparing by using VG model with BC model, we found the BC model is more suitable for the curve of near saturation water content which cannot be measured by centrifugal force. In addition, they also show a high degree of consistent for the influence of parameters on the shape of SWCC—the parameters $\alpha$ and $h_d$ are related to the absorptive capacity of the sandy soil medium and the parameters $m$, $n$ and $\lambda$ more affect the rate of water content change with the absorptive capacity. The study can be used to provide theoretical foundation and lead the field practice.

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**Session Classification**: Poster with refreshments

**Track Classification**: Topic 8 - Groundwater quality and pollution processes
Analyses and Tools to Assess the Landscape Potential for Enhanced Groundwater Recharge and Land Restoration in Darfur - Sudan

Monday, 23 September 2019 16:00 (60)

Darfur landscape is characterized mostly by semi-arid climate and intensively used land: rainfall is concentrated in few months of the year; vegetation coverage is low and erosion rates are high. Conflicts, population growth and poverty also lead to increasing competition on the usage of natural resources. Planning and developing natural resources requires thus an integrated approach which analyses the physical and social contexts (geology, hydrogeology, geographical distribution of people, other social-political aspects) and seek for matching the different users’ demand versus availability.

Taadoud partnership works towards improved Natural Resources Management (NRM) in the five states of Darfur – North, South, East, West and Central. Acacia Water is supporting Taadoud II in identifying and assessing opportunities to implement small-scale infrastructure and increase water availability throughout the year. In cooperation with the implementing partners (NGO’s: CRS, NCA, Oxfam, UMCOR and World Vision), five hydrological catchment areas have been selected as pilot for implementation of 3R-interventions (Retain, Recharge, Reuse).

A series of analyses and tools have been used to better understand the geological conditions and categorise the potential for 3R-interventions. Remote sensing analyses have been carried out to identify geological features and distinguish the different soil coverage in the catchment areas. Satellite imagery and Google Earth imagery were also combined with existing geological and hydrogeological maps to give better insights in the potential and limitations of the project areas.

As a result, a 3R potential map has been produced distinguishing the potential for water storage in the landscape and for in-stream interventions. A SWAT model (Soil & Water Assessment Tool) was also set up for four out of the five catchment areas for a better understanding of the run-off processes and to estimate the expected groundwater recharge.

Based on the results obtained in the desk study and observations made during the field visit, a comprehensive set of measures have been proposed to increase (ground)water availability and reduce soil erosion. The most promising strategy is to promote reforestation to slow down run-off coupled with infrastructure to maximise retention; enhance recharge of shallow aquifers and develop artificial groundwater storage in the wadis bed, by infrastructure such as sand dams and subsurface dams. Such interventions will benefit livelihood activities and create opportunity for land and soil restoration. With the landscape approach we were able to make local stakeholders and implementation partners aware of the opportunities that the landscape offers for enhancing groundwater recharge and availability. Ideally, an IWRM approach (Integrated Water Resources Management) should be implemented in the area to ensure the long-term sustainability of the interventions and maximise stakeholder’s engagement.

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Session Classification: Poster with refreshments
Track Classification: Topic 2 - Groundwater and climate change
Hydrochemical and isotopic study of the salinity anomaly of de Motril-Salobreña aquifer in the environment of La Rambla de las Brujas (Granada, Spain)

Tuesday, 24 September 2019 16:00 (60)

Due to the large number of previous studies realized in the coastal aquifer Motril-Salobreña (Granada, Spain) exhaustive chemical control reveals the existence of a maximun relative of salinity in the groundwater in the central sector, specifically in one well located more than 1500 meters far the coastline. Water is eventually pumped from this well for supplying Motril town needs.

First reports and publications point to the existence of a possible mixture of a freshwater and seawater, so a deeper study have been carried out into this issue. A three boreholes monitoring station was stablished along a perpendicular profile regarding the coastline, but also following groundwater flow lines. A monthly physicochemical control was done in each one of these point in different deeps during the 2014/2015 hydrological year. Mayor, minor and trace ions were determined in all samples, but in some of them the isotopes ratios δ15Nnitrate, δ18Onitrate, δ11B, δ34Ssulfate, δ18Osulfate y 87Sr/ 86Sr were analyzed.

The results confirm that the anomaly is limited to the north of profile marked by the wells in this study, but they are not conclusive regarding the origin of this relatively high mineralization of water. However, results allow to discard present and old water mixture (connate or trapped water), as well as gypsum dissolution (due to the possible presence of this rock in the bottom of the aquifer), as sources of salinity.

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Session Classification : Poster with refreshments

Track Classification : Topic 5 - Tools, methods and models to study groundwater
Population pressure, recent droughts and sea-level rise associated with climate change projections increase pressure on secure water resources, notably on groundwater of the coastal areas like Maputo, Mozambique. The Matola River, located in the west of Maputo, is a perennial river that consists of mostly brackish/salt water originating from groundwater seepage and salinity makes the river water unusable. The main source of the saline groundwater is assumed to be fossil seawater, entrapped in the silty marl and clay dominated aquitard. However, detailed studies about the salinity problem of coastal Maputo city, particularly of Matola River is very limited. This research focuses on the integration of regional hydrogeochemistry, isotopic analysis, and groundwater flow models to trace the source of saltwater and to improve the management of water resources in Matola wetlands. The hydrogeochemical analyses of major ions will reveal the prominent hydrochemical processes responsible for the evolution of groundwater. Water stable isotopes (δ2H, δ18O) results will validate the sources of salinity and mixing processes. Using the result of 13C/14C (DIC) and 36Cl/Cl isotopes, the study aims to calibrate the residence time and flow paths of the already existing groundwater flow and salt transport models for testing the mentioned hypothesis. Based on the overall findings, some adaptation measures will be proposed to cope with the saline groundwater. Investigating the origin of salinity and proposing measures are expected to help in the domestic supply and crop productivity sectors of Matola River adjacent areas. It can also assist the policymakers to take feasible solutions to sustainable groundwater management.

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Session Classification: Poster with refreshments

Track Classification: Topic 3 - Groundwater sustainability and governance
Monitoring system to define the hydrological behaviour of a complex landslide: a case study in the Northern Apennines (Italy)

The aim of this research is to define a specific monitoring system in order to investigate the hydrogeological behaviour of a low permeability heterogeneous medium in a complex landslide. Case Pennetta active landslide is caused by roto-translational slides and complex active earth slides-earth flows and mainly involves sandstones and clays.

Piezometric levels were monitored, over two hydrogeological years, by two multilevel well systems. Discharge and physico-chemical parameters were monitored in several springs and artificial drains to understand the hydrogeological setting and its evolution over time. Mixing processes between groundwater and neo-filtration water were investigated by EC logs performed in the boreholes. In addition, isotopic analyses of δ18O and δD were carried out to define the recharge areas, and 3H analyses allowed to investigate the mean transit times.

Results showed the coexistence of different flowpath within the saturated zones at the slope scale. A shallow, rapid and reactive to the rainfall regime is characterized by fast circuit, that shows EC values of less than 1000 µS/cm in high flow and up to 3700 µS/cm in depletion phase, according to local infiltration processes. The isotopic values also show a great variability over time (δ18O: -7.86 ÷ -6.95‰) and this variation is also observed in artificial drains and springs, according to a very shallow flowpath. 3H content values are indicative of a mixture between sub-modern and neo-infiltration water (mean value 2.95 UT).

Due to the heterogeneity of the medium, a deep, local and more conductive flowpath were found. This circuit shows smoother hydrograph, higher EC values (from 2500 up to 4200µS/cm without any influence by depletion/recharge phases) and more depleted isotope values with less variation. 3H content values underlines long transit times (mean value 0.34 UT).

The monitoring system developed in this study allowed a better understanding of the hydrogeological behaviour in this type of movement, where the heterogeneity of the material involved influences the groundwater dynamics.

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Session Classification : Poster with refreshments

Track Classification : Topic 5 - Tools, methods and models to study groundwater
Introducción de la Tecnología de Medición del Radón-222 como Radiotrazador Hidrológico en la Región Central de Cuba

El Radón-222 es un gas noble radiactivo relativamente abundante en el agua subterránea, por lo que puede ser utilizado como radiotrazador de procesos hidrológicos. Este trabajo presenta la introducción de la tecnología para la medición de su concentración en aguas superficiales y subterráneas de la región central de Cuba. La medición de la concentración de actividad de Radón-222 en agua se realizó con el monitor SARAD RTM1688 y los softwares Radon Vision y Radon in Water Calculator. Se determinó la concentración de actividad de Radón en aguas subterráneas de Jucaral en Cienfuegos, en aguas superficiales de ríos distribuidos por las provincias Villa Clara, Cienfuegos y Sancti Spíritus, en aguas subterráneas de las cuencas Damují y Arimao en Cienfuegos y Hanabanilla en Villa Clara. La concentración de Radón-222 en aguas subterráneas estuvo entre 0,10Bq/L y 100Bq/L y en aguas superficiales entre 0,009Bq/L y 0,168Bq/L. Se confirmó que el Radón-222 es abundante en aguas subterráneas, es escaso en aguas superficiales en general; sin embargo algunas de estas aguas presentan relativamente mayor cantidad de Radón-222, lo cual indica que pueden tener mayor contribución de aguas subterráneas. Aquellas aguas con muy bajo contenido de Radón-222, evidentemente están muy influenciadas por la lluvia. Las aguas subterráneas de la cuenca Arimao presentaron los mayores valores de Radón-222, los menores valores se determinaron en las aguas subterráneas de la cuenca Hanabanilla, en relación con las características geológicas de ambas cuencas. La cuantificación satisfactoria confirma que el Radón-222 puede ser utilizado como radiotrazador hidrológico en Cuba.

Palabras claves: Radón-222, radiotrazador, agua, Cuba

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Session Classification : Poster with refreshments

Track Classification : Topic 5 - Tools, methods and models to study groundwater
Kuldur spa is the most famous and great resort located in the Russian Far East, Amur River region. The geological structure is defined by the contact zone of Paleozoic granites and Proterozoic gneiss. The granite country rocks are intensive altered and fractured. The typical feature of studied waters is a high temperature (up to 100 °C), low TDS (< 0.5 g/l), high pH (> 9). The cations are mostly Na+, less Ca2+ and a few Mg2+. The main anion is HCO₃, the second - SO₄. Water is usually enriched with F-, Si, Al, W, Mo, etc. All waters content high amount of radon (up to 32.4 kBq/l).

The purpose of this work is to study the chemical and isotopic signatures of nitric thermal waters from Kuldur spa and characterize their circulation processes. For solving this task, multiple isotopes δD, δ18O, 3H, 3He/4He, 4He/20Ne, δ13C, 234U/238U together with geothermometer calculation were utilized.

The main gas component is N2 (up to 98 vol.% ) with a trace amount of noble gases (Ar, Kr, Xe, He and Ne), in both dissolved and escaping gas. The methane, carbon dioxide and oxygen contents are minor. The 3He/4He ratio is low 0.19-0.25 and can be considered as dominated by a crustal source. The δ13CDIC values vary from -30 to -18.1 ‰ and testify on the biogenic origin of carbonate specimens. The δ18O and δD are parallel with GMWL showing that the recharge source of thermal water is local meteoric precipitation. Value of 3H are very low up to 0.7 TE which indicate the long circulation time and also confirm no dilution of deep thermal waters with shallow cold water. Our calculation based on Na-K and SiO₂ geothermometers indicates that these thermal waters are reached 130°C and the corresponding circulation depth is about 5 km. According to the 234U/238U dating, the circulation time of the studied thermal groundwater is at about 400,000 years.

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**Session Classification**: Poster with refreshments

**Track Classification**: Topic 5 - Tools, methods and models to study groundwater
Karst terrains appear on all continents and karst aquifers produce drinking water for more than 9% of the world’s population. Although characterised by variable regimes, karst groundwater has excellent natural quality. However, proper evaluation and characterisation of a specific karstified aquifer is one of the basic preconditions for sustainable use and protection of aquifers formed in carbonate rocks. Basic information on the functioning of karst hydrogeological systems can be obtained by analysing the data on the karst spring discharge. These data should be collected by forming a monitoring network at the locations of groundwater discharging, which further analysis can determine the hydraulic characteristics and probable geometry of the observed karstified aquifer. Analysis of hydrographs in the recession period has been conducted for the karst springs Seljašnica (SW Serbia) and Mokra (SE Serbia).

Seljašnica karst aquifer is located in the Southwest Serbia, belongs to the Inner Dinarides and drains the eastern part of the Babine karst plateau built from the Middle Triassic limestone. The Mokra karst spring is in the Southeast Serbia, i.e. in the southern end of the Carpatho-Balkanides of Serbia and drains the eastern part of Suva planina Mountain, which is built of Tithonian and Lower Cretaceous limestones and dolomites. A comparative analysis of the hydraulic conditions of the discharge of these karst springs includes the period 2015-2017 year. The analysis showed the range of yield of the karst springs: Seljašnica Qmin = 0.140 m³/s to Qmax = 6.061 m³/s, while Mokra has discharge Qmin = 0.105 m³/s and Qmax = 4.062 m³/s. The recession analysis was carried out using the Maillet formula for all three years on both springs.

Analysis of the karst spring Seljašnica recession curve showed 4, 2 and 3 micro-discharge regimes in 2015, 2016 and 2017, respectively. On the other hand, the analysis of the recession curve of the Mokra karst spring discharge shows the existence of the 3, 2 and 4 micro-discharge regimes in 2015, 2016 and 2017, respectively. It was noticed that the peak of the Seljašnica karst spring in the recession period is in two cycles (rapid and slow discharge of the karst aquifer), while the outflow of the groundwater at the Mokra karst spring is uniform.

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Session Classification : Poster with refreshments

Track Classification : Topic 7 - Karst Hydrogeology
Study of the quality of irrigation water in the plain of Sidi-Bel-Abbes

Monday, 23 September 2019 16:00 (60)

In the plain of Sidi-Bel-Abbes (Northwest of Algeria), in a semi-arid climate, the use of irrigation is inevitable for most crops. Groundwater are increasingly sought. The aim of this work is the determination of the chemical composition, facies and class of water quality for irrigation of the plain of Sidi-Bel-Abbes. This is more precisely determining the constraints and opportunities of using this water for irrigation of agricultural land in the area of Sidi-Bel-Abbes. A hydrochemical study was carried out which focused on the major elements of the water aquifer. Samples were taken over a period of two months (June and July). The 17 wells are controlled spread across the plain. Analyzes reveal a variety of chemical compositions, samples split between two facies: the sodium chloride and calcium sulfate. Mineralization of water, which is generally high, poses a risk of soil salinization.

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Session Classification : Poster with refreshments
Track Classification : Topic 1 - Groundwater assessment and management
Turbidity dynamics in karst hydrogeological systems. Example of three karst springs from Serbia

Thursday, 26 September 2019 16:00 (60)

Karst groundwater usually is of great quality and doesn’t require any water treatment methods prior water supply, except disinfection and simple filtration. On the other hand, turbidity is one of the groundwater quality parameters that fluctuates rapidly triggered by heavy rains. Increased turbidity often indicates greater number of bacteria in groundwater, usually flushed from the ground surface by storm events. The difficulty in handling this phenomenon is highly transmissive vertical and horizontal conduits of karst hydrogeological systems, along with low transmissivity fractures in rocks (dual porosity). Permanent monitoring of karst springs, as preventive measure in management of karst aquifers, is necessity. Long monitoring time-series make possible performing stochastic analysis to gain insight into the causal relationship between precipitation and karst groundwater quantity and quality parameters.

Karst aquifers represent significant natural resource of Serbia, with potential yield of around 4 m3/s. Research has been conducted during several years in two karst areas of Serbia, but hydrological year from 01/10/2016 to 30/09/2017 has been selected as representative one. Monitoring of quantity and quality of Mokra and Divljana karst springs, in South-eastern Serbia has been established for the purpose of better management of water supply system, as well as monitoring of Selašnica karst spring in South-western Serbia. This research includes stochastic analysis of time series of rainfall, spring discharge and turbidity recorded daily at karst springs for one hydrologic year.

Stochastic analysis of time-series has showed that Mokra karst aquifer has long memory effect (51 days), Divljana karst aquifer has short memory effect (10 days), while Selašnica karst aquifer has memory effect of 27 days. Also, the analysis has showed that rainfalls have short memory of only 2 days, while turbidity have memory 4-5 days. Cross correlation analysis between rainfalls and discharge of Mokra and Divljana karst springs pointed out 10 days delay, however Selašnica karst spring has very low coefficient of correlation. Cross correlation between rainfalls and turbidity of observed karst springs showed less than 3 days delay and little inertia of the karstic systems regarding turbidity. The complex hydrodynamic behaviour related to the system hierarchy is thought to be the origin of turbidity. The fast infiltration through the unsaturated zone causes a flushing effect and a turbulent quick flow in the highly transmissive conduits with very high velocities.

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Session Classification : Poster with refreshments
Track Classification : Topic 7 - Karst Hydrogeology
Conceptual hydrogeological model in a part of the Tempisque river basin, Liberia, Costa Rica

Tuesday, 24 September 2019 16:00 (60)

The study covers is 262.5 km², it is located in the northwestern region of Costa Rica and constitutes part of the Tempisque river basin. This region is one of the driest and fastest-growing areas in the country in terms of development. A conceptual hydrogeological model is proposed here as the basis to carry out specific studies as well as to plan the use of water resources in the territory. The geology is composed mainly of Mio-Pliocene and Pleistocene rocks corresponding to the Bagaces and Liberia formations, as well as some Quaternary alluvial deposits. The Bagaces Formation is composed of a series of pyroclastic flows interbedded with a lava unit and sedimentary layers associated with the explosive events. Crystalline white tuffs correlated of Rio Liberia Unit of Liberia Formation are found overlying the previous formation. West of the study area, Tempisque River alluvium overlying the Bagaces Formation.

Two aquifer systems are identified. The Bagaces aquifer is a complex and fractured system due to the heterogeneities of the reservoir. Some layers of tuffs and paleosols constitute horizons with lower hydraulic conductivities, while in general lavas present the best hydrogeological conditions. The aquifer varies from unconfined to confined, with the hydraulic conductivity is between 3.2x10⁻³ m/d and 31.22 m/d. The transmissivity varies from 2.43 m²/d to 5520 m²/d, with high to very high values in the northeastern sector, high values in the west and intermediate values in the central-western area. The aquifer is classified as considerably heterogeneous.

On the other hand, Liberia is an unconfined aquifer, with transmissivity values between 3.56 m²/d and 54.6 m²/d. It is classified as homogeneous and the hydraulic conductivity varies from 0.0199 m/d to 0.2665 m/d.

The total average rainfall in the area is of 13.9 m³/s, of which 2.05 m³/s (14.73%) is intercepted by vegetation; the runoff volume is 0.35 m³/s (2.51%), mainly limited to the urban area; evapotranspiration is 7.98 m³/s (57%) and the potential recharge to aquifers is 3.46 m³/s, which constitutes only 24.8% of the total rainfall.

Both aquifers are recharged by rainfall infiltration and in the case of the Bagaces aquifer, the recharge is also given by vertical percolation of the upper aquifer, while recharge from mountainous areas is not ruled out. A previous hydrogeochemical study indicates that the water recharged by both aquifers is of meteoric origin, with the water residence time being shorter in the Liberia aquifer than in Bagaces, based on tritium isotopes and CFCs, in both cases being less than 50 years old.

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Session Classification : Poster with refreshments

Track Classification : Topic 5 - Tools, methods and models to study groundwater
The Tubarão Aquifer System - TAS is a permo-carboniferous sedimentary aquifer, deposited in a glacial continental and shallow marine environment (DAEE/IG/IPT/ CPRM, 2005). The productivity is relatively low, presenting transmissivity between 1E-6 to 3E-4 m²/s (Iritani et al, 2009) and hydraulic conductivity between 1E-8 to 1E-5 m/s (DAEE, 1981; 1982).

Municipalities in the outcropped TAS are experiencing economic and population growth, driven by development policy implemented in the late 1980s. They are inserted in the water resources management units denominated UGRHIs 5 and 10 where the water availability has been strongly reduced during the last decades.

In 7 years, the availability per capita reduced over 7%, reaching, in 2017, 981 m³/hab.year in the UGRHI 5 and 1686 m³/hab.year in the UGRHI 10. According to published information, the regular extracted volume of groundwater, authorized by management agency, is less than 30% of the surface water (CBH-SMT, 2016, 2018; CBH-PCJ, 2016, 2018).

Studying the TAS in 12 municipalities, it was observed that groundwater plays an important role in the economic development of the region.

The TAS thickens to west and the well depth in the study area range from 50 to 455 meters. Due to its heterogeneity which imposes a semi-confinement condition, the well productivity is low, with average specific capacity and flow rate of 0.13 m³/h/m and 7.2 m³/h, respectively. In the southern portion of the study area the productivity is higher, where flow rates can be above 30 m³/h per well, allowing its use for public water supply in some municipalities as Tietê, Capivari, Rafard, Porto Feliz and Elias Fausto. The estimated rate in 2015 of 132 public water supply wells was around 0.61 m³/s.

However, the largest number of wells belongs to private users (929 wells) whose pumped volume was estimated at 1.05 m³/s. The industrial sector, with 564 registered wells, is the main user of groundwater. According to SEADE (2019), this sector accounts for 30% of jobs in these municipalities, playing an example of the groundwater importance for the economic development in São Paulo State.

According to TrataBrasil (2019) the total number of wells may be much higher due to the irregular wells not registered by the management agency (about 60% in the São Paulo Metropolitan Region). Besides that, in Capivari and Tietê, where intensive pumping occurs, locally water level drawdown is observed (Iritani et al., 2009; Ferreira et al., 2005).

In addition, radiocarbon isotope analyzes of TAS provided a range of pmc between 0.39 and 79.96, indicating high residence times, greater than 15,000 years BP, demonstrating the use of old groundwater.

These facts demonstrate that the improvement of knowledge of the TAS, especially about recharge processes, is necessary to subsidize a sustainable use of the aquifer.
Presenter(s): Dr GASTMANS, Didier (Sao Paulo State University - Environmental Study Center (UNESP-CEA))

Session Classification: Poster with refreshments

Track Classification: Topic 1 - Groundwater assessment and management
Kuldur spa is the most famous and great resort located in the Russian Far East, Amur River region. The geological structure is defined by the contact zone of Paleozoic granites and Proterozoic gneiss. The granite country rocks are intensive altered and fractured. The typical feature of studied waters is a high temperature (up to 100 °C), low TDS (< 0.5 g/l), high pH (> 9). The cations are mostly Na+, less Ca2+ and a few Mg2+. The main anion is HCO3, the second - SO4. Water is usually enriched with F-, Si, Al, W, Mo, etc. All waters content high amount of radon (up to 32.4 kBq/l). The purpose of this work is to study the chemical and isotopic signatures of nitric thermal waters from Kuldur spa and characterize their circulation processes. For solving this task, multiple isotopes δD, δ18O, 3H, 3He/4He, 4He/20Ne, δ13C, 234U/238U together with geothermometer calculation were utilized.

The main gas component is N2 (up to 98 vol.% ) with a trace amount of noble gases (Ar, Kr, Xe, He and Ne), in both dissolved and escaping gas. The methane, carbon dioxide and oxygen contents are minor. The 3He/4He ratio is low 0,19-0,25 and can be considered as dominated by a crustal source. The δ13CDIC values vary from -30 to -18.1 ‰ and testify on the biogenic origin of carbonate specimens. The δ18O and δD are parallel with GMWL showing that the recharge source of thermal water is local meteoric precipitation. Value of 3H are very low up to 0.7 TE which indicate the long circulation time and also confirm no dilution of deep thermal waters with shallow cold water. Our calculation based on Na-K and SiO2 geothermometers indicates that these thermal waters are reached 130°С and the corresponding circulation depth is about 5 km. According to the 234U/238U dating, the circulation time of the studied thermal groundwater is at about 400,000 years.

The reported study was funded by RFBR according to the research projects 18-05-00445 and 19-55-50002.

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Presenter(s) : Ms LYAMINA, Larisa

Session Classification : Poster with refreshments

Track Classification : Topic 5 - Tools, methods and models to study groundwater
Groundwater surface water interactions in the headwater catchments in Qinghai-Tibetan Plateau, constrained by multiple isotopes and implications of biogeochemical cycling

Tuesday, 24 September 2019 16:00 (60)

Glacial and permafrost hydrogeology is a cutting edge topic in the past decades. As the third pole of the world, Qinghai-Tibetan Plateau (QTP) is featured by its mountainous glaciers and widely distributed permafrost, therefore, can be regarded as an ideal natural laboratory to investigate how the groundwater/surface interaction and the associated biogeochemical cycling are regulated by glaciers and permafrost. From 2015-2018, comprehensive field campaigns have been made to investigate the hydro-geochemical parameters from different water endmembers (groundwater, porewater from hyporheic zone (HZ), lake water, stream water and precipitation) in in three representative headwater water catchments of QTP: Nyang headwater catchment (glacier and permafrost influenced); Parlung Zangbo headwater catchments (glacier dominated); and Yellow River headwater catchment (permafrost dominated). We investigated the multiple isotopes such as stable isotopes, radon-222, and radium isotopes, together with other geochemical parameters, such as nutrients, carbon system constituents, and major irons. The transient storage reactive transport model of 222Rn and radium isotopes are deployed to quantify the groundwater inflow rates, hyporheic exchange rates, hyporheic depths, and water residence time of HZ. Based on the depictions of groundwater surface interactions, the nutrient and dissolved inorganic carbon reactive transport model under transient storages are constructed to quantify the carbon-nitrogen cycling for the headwater catchments in QTP. The spatial distributions of groundwater inflow and hyporheic exchange rates are discussed with the geomorphological metrics of slopes, channel depths, width, sinuosity, upland contribution areas, HZ depths, and HZ residence time. The scaling results of HZ exchange rates and geomorphological parameters are further compared with the HZ exchange regression models derived from numerical modeling. Moreover, the roles of the permafrost and glacier coverage of the upland contribution areas on the the groundwater inflow rate distributions are systematically examined. The influences of groundwater, hyporheic exchange rates, glacier/permafrost coverages, geomorphological settings on the nutrient and carbon export and cycling are fully explored and conceptualized. The study makes the first attempt to quantify the groundwater/interaction and the mediated biogeochemical cycling based on multiple isotopes in the QTP and will shed new lights how the glacier and permafrost influences the groundwater surface interaction in the headwaters in QTP and other areas with similar settings.

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Presenter(s) : LUO, XIN (The University of Hong Kong)

Session Classification : Poster with refreshments
**Track Classification**: Topic 5 - Tools, methods and models to study groundwater
Hydrogeological study of the effects of 2016-2017 seismic sequence on the Pescara d’Arquata spring (Central Italy)

Thursday, 26 September 2019 16:00 (60)

Since August 2016 Central Italy experienced a long seismic sequence including nine Mw 5.0-6.5 events. The strongest shock (Mw 6.5) occurred on 2016 October 30th about 5 km NNE of Norcia Town, 9 km below the surface, as a result of upper-crust normal faulting on Mt. Vettore-Mt. Bove fault system, in the Sibillini mountains. This affected the dynamic of groundwater systems of the area, both east and west of the Sibillini Mountains.

The longest and most reliable series of daily discharge measurements are available for the Pescara d’Arquata spring, located south-east of Mount Vettore, starting from 1985. In the short term, the 2016 seismic sequence caused a discharge increase, lasting from October 2016 to February 2017. In this period the surplus outflow ($2.33\times10^6 m^3$) has been about 30% of the average annual amount of groundwater flowed before the seismic sequence.

Later, the discharge series analysis showed that in 2017 the minimum discharge at the end of the depletion period has been about 25 L/s as low as in 2007 only. In order to determine whether this very low discharge could be linked to climatic conditions similar to those which caused low discharges in other years, the SPI was calculated on the Arquata del Tronto rainfall data in 1985-2018 interval. It was found that in 2017 a discharge lower than 50 L/s corresponded to an SPI value between -1 and -1.5 (moderately dry). On the contrary, similarly low discharges recorded in other years were associated with SPI values closer to or lower than -2 (extremely dry).

Recession periods in the 2003-2018 interval were analyzed and found to fit the Maillet equation. It was observed that the average Maillet depletion coefficient $\alpha$ between 2003 and 2016 has been $6.35\times10^{-3} \ d^{-1}$. After the seismic sequence, the $\alpha$ coefficient has increased, with an average value of $1.27\times10^{-2} \ d^{-1}$. Post-seismic tracer test showed that the connection of the spring to the Mergani sinkhole, located in the Pian Grande area (about 1300 m asl) was no longer found. The $\delta^{18}O$ content recorded after the seismic sequence is more depleted than it was before the earthquake. Data shows both short and long term effects. Short term effect is mainly the surplus outflow between September 2016 and February 2017.

The long term effects are a likely permanent change of the aquifer geometry and/or the recharge area which may be occurred and this fact seems to be supported by the $\delta^{18}O$ variation, suggesting an increase of the mean apparent isotopic elevation. This could be linked to the fact that a portion of Pian Grande does no longer contribute to the spring recharge. The variation of the Maillet $\alpha$ coefficient seems to confirm this hypothesis.

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Hydrogeological study of the effects of a karst aquifer in the municipality of Rome, Italy; TAIZIOLI, Alberto (Università Politecnica delle Marche); VALIGI, Daniela (Dipartimento di Fisica e Geologia - Università degli Studi di Perugia, Italia); VIAROLI, Stefano (Roma Tre University)

**Presenter(s):** FRONZI, Davide (Università Politecnica delle Marche)

**Session Classification:** Poster with refreshments

**Track Classification:** Topic 7 - Karst Hydrogeology
The Pilato Lake (Sibillini Mts., Central Italy): second results of a study on the supposed variations of its hydrogeological conditions induced by the seismic sequence 2016-2017

Tuesday, 24 September 2019 16:00 (60)

The Pilato Lake has glacial origin, is located in the Sibillini Mountains, Central Italy and houses a particular endemism unique in the world: the small crustacean Chirocephalus marchesonii. In the context of a research agreement with the Monti Sibillini National Park, ISPRA is carrying on some studies aimed to evaluate the effects of the 2016–2017 Central Italy earthquakes on the hydrogeological conditions controlling the lake’s evolution. The study, started in July 2018, aims primarily at the reconstruction of the subsoil setting beneath the valley hosting the lake, both in terms of geological and hydrogeological boundaries. In order to define the conceptual model of groundwater circulation and, thus, to evaluate the emptying and recharge seasonal cycle of the lake, hydrogeological surveys and geophysical investigations were performed.

A drone photogrammetric survey allowed a preliminary reconstruction of the lake basin bathymetry that allowed, in turn, the calculation of the water basin volumes in the various observed periods, the estimate of evaporation from the lake surface and the comparison with the information relating to previous years compared to the present study.

The velocity profiles of the seismic surveys have estimated the maximum thickness of debris (detrital and glacial sediments on top of calcareous bedrock) equal to about 12-15 m. Further investigations through GPR will be addressed to the better definition of the geological boundaries.

The physical-chemical characteristics of the waters (T=12-13°C; pH=8-9; EC=60-125 µS/cm) are consistent with those of stagnant and slightly oxygenated waters. The low value of EC of the lake’s waters is in accordance with the prevailing provenance of the lake’s recharge by snow melting and precipitation.

The research program is still in progress and to date we can propose only preliminary remarks. The hydrogeological survey showed the absence of geomorphological evidence of earthquake ruptures: the crisis situation of the lake level in the summer of 2017 was probably due to the dry and warm meteo-climatic conditions of winter-spring 2016-2017. The lake level from its maximum flooded quota in May-June 2018 (completion of snow melting) falls down rather rapidly to the elevation of the Fonte del Lago, which acts as an overflow, and then declines more slowly due to evaporation and infiltration through the soil of its bed down to the minimum levels which, in particular arid years, lead to its drying out.

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Presenter(s): Dr LA VIGNA, Francesco (Italian Geological Survey - ISPRA)
**Session Classification**: Poster with refreshments

**Track Classification**: Topic 5 - Tools, methods and models to study groundwater
In this study, we developed a one-dimensional mobile-mobile model (MM) for contaminant transport in subsurface with depth-dependent reaction coefficients. Two local systems at micro-scale level are involved in this model: a micro-pore system and a less permeable pore system. The breakthrough curves (BTCs) obtained from the MM with depth-dependent coefficients were thoroughly analyzed, where the case with constant coefficients was used as the reference system. The effects of different parameters on BTCs were studied, and a parameter analysis was also performed to illustrate the effects of adsorption coefficient and degradation coefficient on BTCs. Results show that the BTC patterns for the depth-dependent reactions, in which the reaction rate decreases with increasing depth, vary between the two extreme cases with constant-rate reactions in the topsoil and observation depth. The mass transfer coefficient \(\alpha\) plays a significant role in defining the BTC pattern. The double peak changes to a single peak when the value of \(\alpha\) is large enough. In addition, the velocity of the main flow determines the shape of the BTCs while the velocity of the SVD defines the pattern of the dual peaks in BTCs which also tends to be represented by a single peak as the velocity decreases. Finally, we tested the applicability of the proposed model (MM-FD) in the leaching experiments of both field herbicide and conservative tracer in an agricultural area of northeastern Greece, and compared its performance with that of the convection-dispersion equation (CDE) model by Gao et al. (2013), both of which have depth-dependent coefficients. The results showed that the proposed mobile-mobile model with depth-dependent reaction coefficients was able to satisfactorily capture the evolution of metolachlor concentration both at upper and lower depths.

**Primary author(s)**: Mr XIE, Shuang; Dr WEN, Zhang

**Presenter(s)**: Dr WEN, Zhang

**Session Classification**: Poster with refreshments

**Track Classification**: Topic 8 - Groundwater quality and pollution processes
AgriMAR Bangladesh – Managed Aquifer Recharge to provide irrigation water for saline agriculture in the Bagerhat District

Monday, 23 September 2019 16:00 (60)

Agriculture in the coastal plain of Bangladesh faces a number of serious challenges, among which the issue of seawater intrusion that is exacerbated by the effects of climate change. During the dry season most of the surface water bodies of the vast delta area become saline or brackish, making the water unsuitable for irrigation. Farmers are therefore limited to one or two harvests of rainfed crops (usually rice) per year. This project aims at improving livelihoods and climate-resilient agriculture by making irrigation water available during the dry season, which allows farmers to grow an off-season harvest of high-value crops, such as watermelon or bitter gourd.

In 2018, a managed aquifer recharge (MAR) system for the irrigation of crops was implemented in the district of Bagerhat, in the coastal plain south of Khulna, Bangladesh. Constructed as an aquifer storage and recovery (ASR) system, it provides a low-cost solution for storing freshwater in a saline environment to be used for irrigation during the dry season. The abundant monsoon rains provide large amounts of freshwater and applying ASR has proven to be a suitable solution for bridging the water availability-demand gap between rainy season and dry season.

In the project area, rainwater is collected in shallow ponds that can also be filled with river water. The developed AgriMAR scheme features a horizontal drain that is installed parallel to a pond. To reduce the turbidity, water flows from the pond to the horizontal drain through a jute-lined chamber with filter sand. Using a motor pump, a 5 m³ reservoir is filled with water from the drain. The water then infiltrates under gravity in the shallow and deep 4” filters of the well. The infiltration capacity is around 9 m³/h with an overhead pressure of 1.5 to 3.0 m, depending on the water level in the reservoir. The infiltrated freshwater displaces the brackish groundwater and forms a lens at the top of the aquifer. As a considerable amount of infiltrated freshwater is lost to mixing at the boundary of the lens, only the shallow filter is used for recovery.

The simple, low-cost AgriMAR system was constructed with locally available materials and unskilled labor. The annual infiltration volume is estimated to be at least 5,400 m³. Assuming a recovery efficiency of 50% this allows for the irrigation of at least 0.3 ha of high-value crops. A detailed economic assessment showed that there is a positive business case for growing bitter gourd or watermelon using the AgriMAR system.

By providing a low-cost source for irrigation water throughout the year the AgriMAR system can greatly improve the climate resilience of farmers in the delta of Bangladesh, one of the most vulnerable regions regarding climate change impacts.

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Presenter(s) : Mrs BENEDICTO VAN DALEN, Daniela (Acacia Water)

Session Classification : Poster with refreshments

Track Classification : Topic 3 - Groundwater sustainability and governance
Hydrogeological setting of a Rome city sector: shallow groundwater in the right bank of Tiber River inside the G.R.A highway.

Tuesday, 24 September 2019 16:00 (60)

This contribute presents a detailed hydrogeological study of a Rome city sector, in the right bank of Tiber River, approximately inside the GRA highway and focused on the east of “Rio Magliana” stream.

A hydrogeological model of the subsoil of this city sector, more detailed than the most recent Hydrogeological Map of Rome (1:50.000 scale - La Vigna and Mazza, 2015) has been possible to obtain by means of the geologic-stratigraphical analysis, performed starting from the data provided by Environmental Protection Dep. of Roma Capitale (Municipality of Rome) and through the analysis of historical topographic and thematic maps of this sector. Moreover, the most superficial aquifer bodies have been identified.

The archived data have been elaborated by means of constructing detailed hydrogeological cross sections (1:10.000 scale). The water table contours’ elaboration was manually performed by means of triangulation methodology and then improved with visual methodology.

The obtained hydrogeological cross-sections highlighted that in the northern sector of the study area the upper volcanic deposits have an important thickness and base oneselfs on a fine cineritic deposits called, on the geological map (Funiciello et al. 2008), “Tor de’ Cenci Unit”. Going towards the central and southern areas, the volcanic deposits thickness is reduced and the underlying “Ponte Galeria Formation” becomes more thick with the “Pisana Member”, a stratigraphic member made up of three different lithofacies (Pgl 3a, Pgl3b, Pgl 3c). In the study area the “Sandy-clay lithofacies” (PGL3b) (Argille a Venerupis senescens Auctt.) presents a certain continuity. This stratigraphic setting also in conjunction with the water table available data and the springs’ elevations, allowed to suppose that the “Tor de Cenci Unit”, in the northern sector of the study area, and the “Sandy-clay lithofacies” of the “Pisana Member”, in the southern sector, can assume the role of aquicludes of their upper aquifers.

The hydrogeological conceptual model of the analysed sector allowed to detect the presence of two overlapping shallow aquifers bodies, the first in the upper volcanic deposits of Sabatini Mts, and the second in the most superficial sandy sediments of the “Ponte Galeria Formation” that sometimes can result confined.

Both circulations are separated from the underlying deeper regional aquifer, except for the sectors where the stratigraphic setting does not allow hydraulic separation and therefore determines a single groundwater circulation.

This hydrogeological setting has been represented in a detailed Hydrogeological Map 1:25.000 scale.

The detection of these shallow aquifers contributes to the basic knowledge for the protection of local water resources, especially from the anthropic pressure factors that insist on this area.

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Hydrogeological setting of a Rome ...

Presenter(s) : Dr LA VIGNA, Francesco

Session Classification : Poster with refreshments

Track Classification : Topic 10 - Urban groundwater
Risk assessment of water erosion by RUSLE - Lahmer watershed in the Setat plateau in Morocco

Monday, 23 September 2019 16:00 (60)

In Morocco, this erosion is linked to the combined action; the nature and condition of the soil material; relief; vegetation cover; anthropogenic factors (deforestation of landforms, overgrazing, poor agricultural practices and exploitation of clay and limestone quarries) as well as the torrential nature of rainfall which is accentuated by climate change.

The objective of this study is to map the areas vulnerable to water erosion in the Lahmer basin. The approach followed is based on the exploitation of available data in order to map the major factors involved in the erosive process such as precipitation, vegetation cover, soil erodibility and topography as well as their integration into the revised universal loss equation. in soils “RUSLE”. using the geographic information system “GIS”. and remote sensing based on monthly and annual climate data, terrain missions, Landsat multidate satellite images and the digital terrain model.

The final results of the water erosion maps show that the year with the highest rate is 2015, which has experienced a significant rainfall compared to previous years, on the one hand, and the zone has become embroiled in a new one. development path that converts it into an industrial zone and has several units for the exploitation of natural resources that abound in the region, such as quarries made of clay and limestone.

Keywords: water erosion, RUSLE, SIG and remote sensing, spatial aproach, high plateau de Settat.

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Session Classification : Poster with refreshments

Track Classification : Topic 1 - Groundwater assessment and management
Application of Airborne Electromagnetics to Characterize Structure and Stratigraphy in the Indian Wells Valley Groundwater Basin, California

Monday, 23 September 2019 16:00 (60)

Airborne electromagnetics (AEM) has previously been demonstrated effective at defining stratigraphy (coarse texture versus silts and clays, channels versus linear features), and for delineating water quality (brackish water resources and seawater intrusion), especially when integrated with borehole geophysical logs, lithology from well drilling and construction, and water quality data. Additionally, AEM surveys provide much greater spatial coverage than traditional methods in terms of time and resources, resulting in improved hydrogeologic correlation and interpretation between wells. In this project, approximately 800 linear kilometers of AEM data were collected in the Indian Wells Valley (IWV) groundwater basin to define the nature and extent of brackish groundwater resources, including the local and regional structure and stratigraphy.

The Indian Wells Valley (IWV) groundwater basin is located at the southeast termination of the Sierra Nevada Mountains in a tectonically active area of rifting and crustal thinning associated with differential movement along the North American and Pacific plates. The regional setting has been causal to the IWV basin complexity, having formed a half graben with mountain uplift and IWV basin downdrop along the Sierra Nevada Frontal Fault, with multiple associated faults running through the basin. The IWV basin has been subject to a long series of studies, initially to characterize the geology and hydrology, and later to further delineate geothermal potential of the basin, based primarily upon data from wells, surface soils and geologic mapping, and 11 seismic sections. The AEM survey supplemented the existing data distribution, providing a more continuous spatial coverage of the basin.

Results of AEM survey of the IWV basin have shown the utility of the technology for mapping subsurface structure and stratigraphy, with multiple faults visible in the AEM data, showing evidence that internal basin structure controlled the depositional environments. A number of buried channels, alluvial fans and coarse delta deposits as well as fault controlled barriers to groundwater flow were mapped. The AEM data also provided detailed information on the extent of brackish groundwater as well as potential locations for groundwater recharge.

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Presenter(s): PARKER, Timothy K (Parker Groundwater)

Session Classification: Poster with refreshments

Track Classification: Topic 1 - Groundwater assessment and management
Assessment groundwater (springs) in Baumberge and Schöppinger Berg for hydrogeology and ecology purposes

Monday, 23 September 2019 16:00 (60)

This study deals with the spring waters flow in münsterland in west of Germany in the area extended between Baumberge and Schöppinger berg, which represented closed groundwater system and fractured pore system. Eight springs, four in Baumberge (Arning ost, Aring west, Stever a, Stever new), and four in Schöppinger berg (Schwarthof, Wearning, Leerbach and Kirche). The springs have been addressed for the purpose of water evaluation for hydrogeology and ecology. In order to meet the objectives of this research, all springs were sampled and analyzed three time in November 2018, January and April 2019 for field parameters (the electrical conductivity, pH value, temperature, dissolved oxygen concentration, While for two time November 2018, and April 2019 for major cations (Mg2+, Ca2+, K+, Na+, Al +, Sr2+), major anions (SO42-, Cl-, HCO3- ) minor anions (PO43-and NO3-) as well as the heavy elements that included (Pb, Zn, Cd, Ni, Fe, Mn, Cu, Cr) and total organic carbon. In addition to isotopes δ34S and biological analysis such as biomass, activity, furthermore faunal measurements for example body size (macrofauna and meiofauna), the ratio of stygobiont to stygoxene fauna and the number of stygofauna per groundwater filled aquifer volume. The organisms were separated from sediments, counted and pre-sorted into taxonomic groups (crustaceans, oligochaets, water mites, nematodes, turballarians). All crustacean groups, which constitute the major part of the animals in groundwater samples, and oligochaets were determined to species level, whilst the remaining taxonomic groups were identified to order or higher level. The results revealed that the springs belong to the classified as Ca-HCO3, which show that most the same hydrochemical properties and only slight variations were observed. Compared to priveous study, there are no major changes in hydrochemistry. However, the evolution of nitrate concentrations in groundwater, which has been described shows a tendency to increase NO3 Concentration. In contract the ecological result refer to determination of the groundwater animals, more from 7 groups of individuals were identified and a total of 642 Copepoda Cyclopoida, 14 Copepoda Harpacticoida, 23 Ostracoda, 17 Nematoda and estimated 162 Nauplius larvae could be detected over the sampling period. The determination show the Arning west and Leerbach largest biodiversity, which is probably due to the high food supply. At the sources. At Kirche no more species were detected. The reason for this could be an influence on the settlement or lack of detritus as a food source from the development in addition to defecult fauna sampling in this spring.

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Session Classification : Poster with refreshments
Track Classification : Topic 1 - Groundwater assessment and management
Bauru Aquifer System, State of Sao Paulo, Brazil: Conditioning factors of water level variations

Monday, 23 September 2019 16:00 (60)

The Bauru Aquifer System is characterized as a sedimentary aquifer, of predominantly free condition, whose recharge is associated with the direct infiltration of precipitation. This aquifer is the main source of public and private water supply in the western portion of São Paulo state, a Brazilian industrial and agricultural pole. The Bauru aquifer has been monitored as part of the Groundwater Monitoring Network, maintained and operated by the Geological Survey of Brazil. In this context, the present study contemplates the investigation and multi-thematic analysis of the intervening factors of the correlation between groundwater level response, rainfall events and anthropogenic alterations, with the purpose of increasing the knowledge of the potentiality of the Bauru aquifer system. Time series of groundwater and rainfall data were also analyzed and evaluated in order to identify the factors that could influence this relationship, such as: composition of the lithological profile above the filter in each well, thickness of the unsaturated zone, specific capacity of the well, number of production wells installed within a 5km radius, soil types and cover in the region. The time series analysis was conducted by using simple correlation between the groundwater level series to verify their similarities, and cross correlations to determine precipitation influence on the wells static level, in order to estimate the necessary time for water to infiltrate and recharge the aquifer, increasing the static level. Subsequently, the data was spatialized using ArcGIS and a multicriteria analysis was performed, assigning weights to the different variables in order to explain the time series correlations. Based on the identification of the interactions and influences of the aforementioned factors, a correlation between groundwater level and the rainfall was identified. This correlation is mainly affected by the lithological profile above the filter, the specific capacity of the wells and the number of production wells located within a radius of 5 km. Series with rapid responses to rainfall events were generally associated with essentially sandy lithographic sequences, specific capacities above 0.29 m³/h/m or with the number of production wells below 10. On the other hand, the absence of correlation or very slow response to rainfall was associated with wells whose lithographic profile had clay layers that could lead to confinement, or had a specific capacity lower than 0.29 m³/h/m associated with a large number of production wells in the surroundings. Additionally, there was a significant water level decrease during a severe drought between 2013 and 2015, corresponding to the same period of the water crisis in the State of São Paulo.

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Presenter(s) : Ms BARCELOS BARBOSA, Marcela

Session Classification : Poster with refreshments

Track Classification : Topic 1 - Groundwater assessment and management
Hydrogeotoxicity assessment in aquifer systems of Malaga province (S Spain): a preliminary approach to evaluate the potential risk of groundwater consumption for human health

Monday, 23 September 2019 16:00 (60)

The increasingly water quality impairment due to anthropogenic pressures and environmental factors is one of the major public concerns and its control and management remain still challenging. Groundwater is highly vulnerable to human-induced pollution effects and, therefore, appropriate monitoring programs and representative groundwater quality stations are crucial to control pollutant levels for evaluating the qualitative status of aquifer systems as recommended by the EU Water Framework Directive. In Málaga province, 33 groundwater bodies hosted in two main river catchments (mostly Guadalhorce river draining to the Mediterranean Sea) partial or totally supply almost 1.5 million of inhabitants. Thus, the principal natural and induced factors such as the wide diversity of geological exposures -including those containing high solubility minerals-, the relatively high extension of cultivated areas, as well as the very often insufficient treatment of waste waters in urban and rural settlements, are demonstrated to endanger the groundwater quality in aquifers across the Málaga province.

In this study, the regional assessment of toxicity levels in groundwater (understood as a potential risk for the human health), have been performed focused on selected inorganic (SO4-2, Cl-, F- and trace metals) and organic pollutants (N-compounds and plaguicides). To that, the statistical treatment of public water quality databases has been performed and single hydrogeotoxicity indices has been applied to evaluate the exposure levels for drinkable groundwater, according to national water regulations and international recommendations.

The groups of selected chemicals were categorized by means of the resulting toxicity levels (extremely toxic, highly toxic, moderately toxic and little toxic), but also based on the adverse effects potentially caused over the functional groups of human body (i.e. genotoxic, neurotoxic, hormonal disruptor, etc.). A hydrogeotoxicity (HGT) threshold equal to 1 was set up, according to precedent studies conducted in Spain, from which groundwater from aquifers are potentially considered toxic for human health in case of prolonged consumption. The first results obtained in this work suggest that HGT values for the evaluation of individual chemicals range between 0 (for total sum of plaguicides) and 2.1 (for SO4-2). Accordingly, 12% of total aquifer systems studied show HGT values >1 for inorganic and organic-derived pollutant such as iron, manganese, nitrate, sulphate and glyphosate, which reflects deficient qualitative status and significant groundwater quality impairment in the main cultivated areas of the province. The evaluation of groundwater toxicity must be included in the groundwater quality control programs performed by health authorities from the quantification of the susceptibility to health risk for citizens. Additionally, this type of human health-oriented hydrogeological research should be linked to epidemiological studies in medical centres to predict potential mid/long-term consequences of polluted groundwater intake in the human population.

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Session Classification : Poster with refreshments

Track Classification : Topic 1 - Groundwater assessment and management
Hydrogeological Conceptual Model in a sub-arctic catchment at Montmorency Forest (Canada)

Thursday, 26 September 2019 16:00 (60)

The Ruisseau des Eaux Volées catchment (BEREV) is located in the Montmorency Forest, 77 kilometers north of Quebec City along highway 175-N. It drains an area of 8.8 km² with elevations between 541 and 979 meters above sea level. Hydrological data from 1967 to 1996 show an average annual rainfall of 1421 mm, an average annual temperature of 0.7 °C, and an average streamflow of 0.313 m³/s at the catchment outlet. Surficial deposits cover approximately 80% of the catchment. They are unconsolidated deposits mainly composed of till and fluvioglacial material with very little clay. The remaining 20% are charnockitic gneiss rocks.

The BEREV was first investigated in 1965 and since then research has been carried out on topics such as: radiation and albedo (Bernier and Plamondon, 1983), evapotranspiration (Mathieu, 2006), snow melting (Jones et al., 1986, Prévost et al., 1990), interception (Prévost and Plamondon, 1987), water quality (Beaudin, 2002, Tremblay et al., 2009), and soil moisture content (Barry et al., 1988, D’Orangeville et al., 2016), among other topics related to forestry. However, the only hydrogeological study available is Rochette (1971), who identified four hydrostratigraphic units, calculated the water balance of the catchment, and identified groundwater flow patterns. Since then, there have been no other studies of the groundwater system besides Schilling et al. (2018) who studied the snowmelt contribution to the groundwater recharge analyzing the dissolved gas with a portable mass spectrometer.

The present study shows the hydrogeological conceptual model of the system considering recent measurements of water table. Is described the geomorphology (influence of topography in the system), hydrology (behavior of precipitation and its influence, discharge and evapotranspiration data), and 3D geological model is proposed.

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Session Classification : Poster with refreshments

Track Classification : Topic 5.4 - Innovative approaches for understanding groundwater flow systems
Hydrological tracers for assessing transport and dissipation processes of pesticides in a model constructed wetland system

Tuesday, 24 September 2019 16:00 (60)

Constructed wetlands have become widespread for pesticide mitigation. Fate and transport of reactive compounds inside these systems involves complex physical, chemical and biological processes that are still not fully understood. Hydrological tracers have been proven to be cost-effective tools to investigate pesticide transport and associated risks in these environments. However, most studies have considered constructed wetlands as “black box” systems. Here we present a novel approach that combines the use of hydrological tracers and high vertical-resolution sampling and monitoring to evaluate pesticide transport and dissipation processes within a wetland system on a long term basis and detailed spatial scale. Three tracers with different sorptive and reactive properties (bromide (Br), uranine (UR) and sulforhodamine B (SRB)) were applied together with three selected pesticides (boscalid, penconazole and metazachlor). The influence of vegetation and alternating different hydrologic conditions on pesticide transport and dissipation were evaluated by comparing a vegetated with a non-vegetated section of the system and by alternating periods of saturation and drying, respectively. Breakthrough curves obtained at different sampling depths revealed that the solutes were not equally distributed within the constructed wetland. Pre-injection conditions, i.e., system at field capacity, probably caused heterogeneities as a result of the existence of water-filled pores in the areas adjacent to the sampling ports of the sandy layers, especially in the middle sections. This was evidenced by a delay in the arrival of the breakthrough peaks. Data also revealed that a higher mass of solutes was transported to the vegetated part of the uppermost layer. We hypothesized that the plant roots could have acted as a shortcut. The strong temporal and spatial correlation found between Br, UR and metazachlor suggested that these solutes experienced greater transport than SRB, boscalid and penconazole, which judging by their rapid decrease in their concentration mostly underwent sorption. This was later confirmed by their similar gradual increase in accumulated mass recovery at the outlet during the flushing phase. Biochemical transformation contributed to the dissipation of metazachlor, as evidenced by the measurement of its transformation products, whose peaks were detected when the aerobic conditions were promoted. This study represents a first approximation to the joint use of hydrological tracers and high vertical-resolution sampling and monitoring to study pesticide behavior inside constructed wetlands with great spatial and temporal detail. Further experiments need to be done under field conditions coupled with mathematical modeling to provide additional insights into the complex phenomena related to transport and dissipation of pollutants in wetland systems.

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Session Classification: Poster with refreshments

Track Classification: Topic 8 - Groundwater quality and pollution processes
Spatial-temporal changes of the infiltration signal in a geologically complex aquifer using isotopes and natural tracers. A case study from Southern Spain.

Thursday, 26 September 2019 16:00 (60)

Abstract

Advance in the knowledge of the infiltration processes in karst aquifers is crucial to achieve a better evaluation and management of water resources. In this work, changes in natural tracers (NO3-, TOC and intrinsic fluorescence) and in the isotopic composition (δ18O and δ13CTDIC) of groundwater through a karst aquifer in Southern Spain have been tracked for a period of 2 years. The spatio-temporal variations of these parameters in the water samples from the rainfall, soil at different depths (from porous capsules installed at 30 and 60 cm below surface), and from 2 karst springs (overflow and permanent) have been simultaneously analyzed. Results show the highest TOC values of the soil water, while the lowest ones were recorded in the groundwater of the permanent spring (base level of the aquifer). However, the highest concentrations of NO3- was registered in the waters collected in the overflow spring. The mean values of δ18O were similar at all sampling points, while an increase towards less negative values of δ13CTDIC, from the soil water to that drained by the permanent outlet, is recorded. A rapid transference of infiltration signal through the vertically distributed compartments of the aquifer (soil-epikarst-unsaturated-saturated zone) can be inferred after analyzing the temporal variations of the considered parameters. This is due to the existence of a remarkable karst development in the unsaturated zone of the aquifer. Nevertheless, the infiltration signal is gradually buffered along flowpath towards the permanent spring due to the geological complexity and the existence of a thick saturated zone at the southeast border of the aquifer, which results in a homogenization of the input signal. The joint analysis of the data permits to deduce detailed insights about the dynamics of groundwater recharge through karst aquifers, as well as a better understanding of the mineralization and degradation of organic matter from the soil to the springs. Moreover, results denote the coexistence of fast and slow flows in the aquifer. In this way, it is important to emphasize that a continuous record of the infiltration signal through the whole aquifer is a current challenge in karst hydrogeology, because of its significance in the quantitative assessment with physically-based modelling approaches under different climate change scenarios.

Key words: karst aquifer, soil water, natural tracers, isotopes, spatiotemporal evolution, Southern Spain.

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Session Classification : Poster with refreshments

Track Classification : Topic 7 - Karst Hydrogeology
The monitoring and management of groundwater is a challenge. In times of water scarcity and in area with freshwater shortage, injecting or pumping water into an aquifer for storage and use at a later time, known as Aquifer Storage and Recovery, or ASR, is gaining importance. ASR can be an efficient technique to store freshwater surpluses for times of demand. During times of plentiful water, extra water can be withdrawn from a river (or other source) and then injected and stored within an aquifer. When the original water source runs low due to drought, low rainfall or other causes, this water can then be pulled from the aquifer and used.

Some ASR facilities inject treated wastewater rather than surface water into an aquifer, while other facilities inject groundwater from a different aquifer. However, the geochemical changes during the injection/retrieval as well as the hydrological changes and influences need to be assessed thoroughly. The formation of deposits and complexes can clog the systems and reduce the quality of the water. Also, in brackish-saline aquifers for instance can the density-driven flow result in limited recoverability of freshwater.

The recently developed iFLUX technology uses a modular passive flux sampler that provides simultaneous in situ point determinations of a time-averaged target compound mass flux and water flux. The sampler is typically installed in a monitoring well where it intercepts the groundwater flow and captures the compounds of interest. The sampler consists of permeable cartridges which are each packed with a specific sorbent matrix. The sorbent matrix of the water flux cartridge is impregnated with known amounts of water soluble resident tracers. These tracers are leached from the matrix at rates proportional to the groundwater flux. The measurements of the contaminants and the remaining resident tracer are used to determine groundwater and target compound fluxes.

The iFLUX sampler technology is being applied in two ASR field projects and has proven its operation and benefit. The modular design enables to determine several parameters at the same time. Currently, 6 cartridge types are validated and available: 1 groundwater flux cartridge to monitor speed and direction of flow and 5 compound cartridges to monitor different compounds – nutrients, VOC’s, metals & heavy metals, free cyanides and 1,4-dioxane. Cartridges for PFAS and pesticides are currently being developed.

The two ASR cases will be presented, together with the iFLUX technology application.
Application of the COP model for vulnerability assessment of the Paraw-Bisetun karst aquifer

Thursday, 26 September 2019 16:00 (60)

Karst water aquifers are highly sensitive to contamination that can rapidly spread and endanger their water storage. This paper aims to estimate the vulnerability of the Paraw-Bisetun karst aquifer to contamination using the COP model. The COP model employs three parameters - concentration of flow (C), overlying layers (O), and precipitation (P) - to assess the vulnerability of karst water to contamination. Utilizing the COP model, 60/46%, 24/61%, 12/07% and 2/86% of the study area was labeled, with respect to vulnerability, as very high, high, moderate and low, respectively. The most vulnerable regions include thick-bedded Bisetun lime inscriptions and have the highest amount of precipitation with low density pasture vegetation. All the identified sinkholes belong to this class and include limestones. The COP model results imply that the Peraw- Bisetun Karst aquifer is one of the highly vulnerable aquifers. Considering the location of these regions, with respect to water sources within the study area, a higher contamination rate is expected for the Berenjan, Varmenjeh, Sohrab, Komeijeh and Barnaj mineral water springs.

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Session Classification : Poster with refreshments

Track Classification : Topic 7 - Karst Hydrogeology
Groundwater resources-climatic changes-energy nexus in Punjab province of Pakistan

Pakistan is an agricultural country having an irrigation-based economy which puts it as the 8th largest food-producing country where irrigated agriculture contributes more than 90% of food requirements. To meet the food and fiber requirements of tremendously increasing population, more lands need to be put under irrigated agriculture for which ever-increasing demand for water exists. Pakistan has become 4th largest user of groundwater after India, USA and China and almost 40-50% of irrigation water requirements are being met from groundwater in Punjab Province of Pakistan. Thus groundwater has become major input for the livelihood of tinny farming communities, especially in rural areas. Like other parts of the world, water resources of Pakistan are under serious threats of global climatic changes. Changing patterns of rainfall, floods and droughts have led to uncertainties and deficiency in surface water flow putting tremendous pressure of groundwater reserves. A large aquifer under the Indus Basin of Pakistan serves as a buffer zone for floods and droughts. Pakistan lies in heat surplus zone on the globe and is suffering adversely from the impacts of global warming. Pakistan has become 10th most climate-vulnerable country although it is 135th in GHG emissions. Droughts coupled with ever-increasing water demand have led to the over-depletion of the aquifer. As the water levels in the aquifer fall below a critical limit cost of pumping increases many folds taking this natural source of living away from the normal bound of its consumers. Under the current scenario, the major chunk of energy resources (electricity, diesel, solar) is consumed in Pumping the groundwater. Burning off more fuel ultimately contributes to environmental pollution as well. Groundwater is a major source of domestic, industrial, livestock and other commercial and societal needs. Punjab Irrigation Department has installed about 2500-3000 observation wells throughout the canal command areas to monitor the groundwater levels both in rural as well as urban areas. Results have indicated that in urban and rural areas groundwater levels are falling at the rate of about 2.5-3 m and 0.3-1.0 m respectively. Out of the total study area, more than 50% area has been found under depth to water table more than 20 ft. It has further been observed that by falling groundwater levels from 7 m to 18 m, the cost of pumping has increased about 125%. At the same time, it has been found that floods recharge the alluvial aquifer significantly. Quality of groundwater is also deteriorating with the passage of time. Major causes of over-exploitation of groundwater and some recommendations for its sustainable and climate-resilient use have been outlined the paper.

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Session Classification : Poster with refreshments
Track Classification : Topic 3.1 - Groundwater and water security in developing countries
People are getting even more aware that their lifestyles, habits and choices can affect the environment. One of the natural heritages to pay more attention to is surely the water. Water, besides being the basis of all natural ecosystems, is also fundamental for everyday life, both as direct consumption and as virtual water. The availability of safe water for drinking purpose varies greatly, depending on both climatic conditions and resource management. The issue of groundwater management, however, must not be limited only to those countries where water scarcity is evident but also where there seems to be water for everyone. For this reason, over the years, various projects have been developed to raise public awareness of water savings. Another issue that recently raised scientists’ and civil society’s attention is the impact of single use plastic that often becomes a stray – and ubiquitous- waste after its first use. Combining these issues, it was easy for public opinion to find one of the main culprits in bottled waters. The bottled water business is developed at all the latitudes of the world, with China, USA and Mexico as Top Bottled Water Consuming Countries (with a total of approximately 110 billion L/year). At European level the Italy is the first country with approximately 14 billion L/year. The quantity, quality and accessibility to drinking water in Italian homes does not seem to justify a market that involves (in 2018) 255 brands of water for a business of approximately 2.8 billion €. The reasons behind buying bottled water are many and often not justified. The knowledge of our drinking water supply systems and the bottled water industries can lead us to unforeseen conclusions that need to be food for thought on how to improve ourselves and may challenge hydrogeologists for a better engagement in water protection.

Early career hydrogeologists must be a preferential vehicle of both research and educational disclosure to people and to water managers. The achieved scientific results of the qualitative and quantitative status of the groundwater resources should be fundamental tools for a wise management in order to reduce future water crisis. At the same time, the divulgation through the social media and public conferences could increase the awareness and the sensibility of the people to the water protection.

Knowledge is power, and a conscious choice in any case is a better choice.
A Versatile Multi-Port System for High Resolution Groundwater Monitoring in Rock and Overburden

Monday, 23 September 2019 15:00 (15)

Characterization and monitoring of groundwater using boreholes is most effectively and efficiently done when each hole is equipped to measure hydraulic head and water samples can be collected at many depths, with each depth interval sealed off from groundwater above and below to minimize short-circuiting in the natural flow system. Multi depth installations in single boreholes are done using nested wells (several conventional wells: each with a screen) or using assembled multi port systems (MPSs). This presentation concerns a new design of MPS referred to as the G360 MPS, which is a major redesign of that described by Cherry and Johnson, 1982. Although many MPS are reported in the literature, only a few are commercially available beginning with the Westbay system in the late 1970’s, but MPS are generally underused by the groundwater profession. The G360 MPS has versatility in several borehole diameters in both bedrock and overburden. It is modular in design with ports attached to casing lengths of standard Schedule 80 PVC casing (2, 2.5, 3, 4-inch ID). A polytube (e.g. polyethylene, nylon, HDPE, Teflon) attached to each hole port extends to surface to form a standpipe well internal to the PVC casing. The number of ports (wells) depends on the inside diameter of PVC casing and the outside diameter of the tubes. More than 18 G360 MPS have been installed to depths up to 150 m in four different hydrogeologic settings, including bedrock and overburden, with number of ports between 8 and 18 and tubing inside diameters between ⅜ to ¾ inches. The components are standard PVC pipe machined and small off-the-shelf parts for local manufacturing, simple assembly and installation. In overburden holes, sand is emplaced around the ports and bentonite forms the seals. In bedrock, the systems have light-weight rubber packers, either removable or permanent. With its simple manufacturing using readily available materials and installation in many-sized boreholes, the G360 MPS is aimed at global use. During the 6 years since the first installation, much progress has been made in demonstrating the performance of the G360 MLS using various drilling methods, borehole diameters and port configurations. Performance in karst, maximum depth capability (likely 200-300m) and alternative packer seal materials remain to be tested.

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Session Classification : Parallel

Track Classification : Topic 5 - Tools, methods and models to study groundwater
Traceability analysis of calcium ions in water after grout curtain at dam site

Thursday, 26 September 2019 16:00 (60)

The leakage water in dam corridor behind the grout curtain is generally characterized by "medium-strong alkali, high mineralization", especially the concentration of calcium ions in the solution is greatly increased compared to the water in the reservoir before the dam. And the formation of calcium precipitates is closely related to the composition of the solution. Calcium ions in the solution are mainly derived from the dissolution of cement stones in the grout curtain and some soluble rocks containing calcium (such as limestone, dolomite, etc.) in the bedrock. According to the different contact and hydrodynamic conditions, the water-rock-curtain interaction system is divided into three types: "lake type", "river type" and "groundwater type". A time-varying model of calcium ion concentration of each type was established and solved by PHREEQC software. The purpose of this paper is to quantify the traceability problem of the target components in the solution under the interaction of water, rock and curtain.

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Session Classification : Poster with refreshments

Track Classification : Topic 7 - Karst Hydrogeology
Groundwater pollution: sources and risks.

Tuesday, 24 September 2019 16:00 (60)

Recently, issues related to groundwater pollution are more than relevant. Not only megapolices, but also small settlements, are literally mired in mud, which is reflected in the groundwater flowing in the area. For a decade, we have been studying the quality of groundwater in St. Petersburg, Russia. And the results are mixed. On the one hand, industrial facilities have declined and their impact too. On the other hand, the population is growing and along with the consumption of raw materials, the volume of environmental pollution is growing. Thus, the value of water pollution is changed. The number of contaminants is modified.

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Session Classification : Poster with refreshments
Track Classification : Topic 8 - Groundwater quality and pollution processes
Sensitivity analysis of correlation parameters of soil-water characteristic curves of biofilm-affected soils

Tuesday, 24 September 2019 16:00 (60)

Better understanding of the interaction among biofilm, soil, and water quality may produce an efficient and economic technology for improving the water management of sandy soils. At present, most soil-water characteristic curves researches were focused on the single soil medium or the medium containing single expansive solute. However, the quantitative understanding of the way biological activity alters hydraulic properties is a major key in understanding and engineering relevant systems such as soil aquifer treatment, bioremediation, and wastewater irrigation. In this study, we measured SWCCs of different particle sizes pure sandy soils (low suction range) by sand-funnel method and sandy soils mixed with different biofilm analogue (xanthan, humic acid, and bovine serum albumin) concentrations (high suction range) by centrifugation and sand-funnel method, respectively. The sensitivity of correlation parameters of soil-water characteristic curves obtained from Van Genuchten model was analyzed by single-factor perturbation analysis method which was the change curves of solute transport concentration caused by changing a single variable in the Hydrus-1D model. We measured the SWCCs of fine sandy soils amended with different biofilm analogues fractions. The results showed the polysaccharide fractions was significant for changing the hydraulic properties of soils and humic acid and protein materials had little effect. In addition, the percolation of humic acid with water flowing had the risk of groundwater quality pollution. For the sensitivity analysis by using single-factor perturbation analysis method, we found the saturated water content $\theta_s$ had important effect on solute transport to reach equilibrium concentration. Therefore, the accuracy of the VG model parameter $\theta_s$ should be guaranteed in the practical application of soil media affected by biological activities. Such an evaluation is useful for microbial ecology research, where the amount of water available to soil bacteria is of interest, and for the analysis and design of bioremediation processes performed in the unsaturated zone, where high bacteria and EPS concentrations exist.

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Session Classification : Poster with refreshments

Track Classification : Topic 8 - Groundwater quality and pollution processes
Transboundary Aquifers: Groundwater Management and Governance in a Water Scarce World

Tuesday, 24 September 2019 09:00 (30)

With the exception of most island nations, every country on the globe is hydrologically connected to its neighbors. This is especially evident in the more than 600 cross-border aquifers that have been identified world-wide and that are being exploited to varying degrees. Surprisingly, and in contrast to the more than 3,600 treaties and agreements governing transboundary rivers and lakes, there are currently only five treaties and a small handful of informal arrangements in place for transboundary groundwater resources. This presentation will provide an overview of the governance of groundwater resources in an international context. It will also address the role that science and policy have in supporting the further development of such regimes, and the role that the International Water Resources Association has taken in bridging the science-policy interface.

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Session Classification : Plenary

Track Classification : Topic 1 - Groundwater assessment and management
Groundwater and socioeconomic development in Latin America

Thursday, 26 September 2019 14:20 (30)

The role that groundwater plays in the economy and in promoting social welfare in Latin American countries is underestimated. The tube wells are mainly drilled to provide water to private initiative. Many of these are not registered, which makes it challenging to evaluate the type of use, the volumes extracted, and the economic and social values. Except in regions where groundwater dependence is very high, or water conflicts are exacerbated, such as in Mexico or some regions in Chile, the illegality of tube wells is generally over 60-70%, even in countries with organized management systems such as Argentina, Colombia, and Brazil. Groundwater is a sole or complementary source of 45-55% of economic activities in the city and the countryside, and it has increased exponentially in recent decades. The difficulty in controlling catchments within a traditional management model, supported by “command and control” mechanisms, is due to: i) the detection of the impacts, caused by excessive extraction, can take decades; ii) the cause of the impact is usually associated with numerous users, making their quantification and liability difficult; and iii) as a rule, control and enforcement institutions have insufficient budgets and personnel. Such reality brings to the discussion the need to implement new mechanisms to improve groundwater governance. Among them, it is becoming increasingly evident that schemes that affect the participation of users (bottom-up approaches) in the management process are essential and should complement the control exerted by governmental institutions.

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Session Classification : Plenary

Track Classification : Topic 9 - Groundwater and socio-economic development in Latin-America
New city planning policy processes – creating a prescient awareness of groundwater for future places and people

Tuesday, 24 September 2019 14:20 (30)

Groundwater is a crucial resource for the resilient and sustainable development of nearly all cities in some way – whether as a key component resource in public water supply, to integrated flood risk management, potential renewable shallow geothermal heat, or roles in contamination pathways and ground stability. The roles and interactions of the resource with urban development are manifold and cross-cutting, but often are not addressed in a comprehensive way.

New urban planning approaches are necessary not only for cities to achieve key outcomes of improved health, low carbon growth, and environmental quality, but also to meet rates of urbanisation and mitigate increasing climatic variability. Current trajectories estimate the world’s urban population in 2050 will be equivalent of the world’s total population in 2004. Both the number and size of cities worldwide is growing, with highest rates of urban growth in Africa and Asia.

City Development Plans and National Planning policy are the key spatial strategies which will deliver our future cities around the world, in a wide variety of landscapes. It is essential these policies are developed with increased awareness of the role, and various interactions, groundwater can play in the urban context, alongside other environmental facets. This will require increased professional collaboration in city planning; and the realization of more effective evidence processes throughout city development processes. Both of these are vital to achieving more effective and pertinent cascades of information, and a prescient awareness of how groundwater can be best harnessed and managed to deliver future cities.

This presentation provides a review of some of the roles and interactions groundwater has across range different urban geographies; and, evaluates some of the different knowledge exchange approaches used in Europe to develop earlier cross-sectoral awareness of the roles of groundwater in cities. The presentation examines some new, emerging planning legislation and evidence processes in Europe; the lessons learnt so far; and the changing relationships and knowledge exchange required to support these.

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Session Classification : Plenary

Track Classification : Topic 10 - Urban groundwater
Canal de Isabel II (CYII) is the main water and wastewater service provider in Madrid Region, supplying services to more than six million consumers. Water supply is accomplished through 14 dams which store 946 hm³. In extended periods of drought and/or disruptions in the water supply system, CYII is able to produce up to 70 hm³ per year from 68 wells located in the Tertiary Detrital Aquifer of Madrid (ATDM). Over the last 25 years, CYII has produced 300 hm³ from the ATDM during five significant pumping periods, each of them ranging from 12 to 18 months.

Data management on complex environment means a challenge itself. Adding all related issues of any industry, as maintenance, construction, QA/QC, to the more classic task of hydrogeology as modelling, groundwater sampling..., trigger the problem to a next level. In order to tackle this problem, Canal de Isabel II is handling a powerful package of tools, focus on keeping data available and stable along the time in its well network.

From database to calculus software are provided from solid international tech companies which guarantee a long term usable framework.

This poster shows appliance of each software, interactions and main capabilities that any user can get from them. Each of these softwares are feed with data either manually or taking raw data from sensor, gauges or digital signals.

Eventually this set of software and information work as a decision aid software which let us to analyze, schedule and react to any new event or information by simplifying and reducing time consuming task.

Our groundwater database provides a quick update to our Modflow model to conduct groundwater supply scenarios and aquifer response for short and long term pumping periods.
Managed Recharge to Restore Aquifers: Past, Present and Future

Monday, 23 September 2019 10:00 (30)

Aquifer depletion and contamination are so widespread that have become a global problem. Worse, depletion causes groundwater dependent systems to suffer and loose a portion of their environmental services. Managed Aquifer Recharge (MAR) has evolved to become the only realistic remediation option, other than stopping extractions, which is often impractical. Yet, actual implementation of MAR is hindered by numerous difficulties, both technical (clogging, maintenance, etc.) and legal (inflow quality requirements are often so strict that rainfall does not meet them). We revise how to address these difficulties. Specifically, we describe the concept of a reactive layer to enhance contaminant removal process during soil passage. We conclude that MAR should, and probably will, become a conventional step of all waterworks.

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ORIGINS OF SALINITY IN THE AQUIFERS OF SAHEL EL HAOUZIA, REGION OF DOUKKALA (WEST MOROCCO)

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ORIGENS OF SALINITY IN THE AQUIFERS OF SAHEL EL HAOUZIA, REGION OF DOUKKALA (WEST MOROCCO)

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ABSTRACT
The Sahel of El Haouzia, is part of the Moroccan Atlantic coastal plain and includes an aquifer system forming surface water contained in the sandy formations and clastic limestone of the Plio-Pleistocene and a deep-water table in the marly limestones of the Cenomanian. The groundwater of the aquifer system of El Haouzia, are characterized by high levels of salts, with conductivities that vary between 2 to 7 ms / cm. This high salinity can, in the short time, affect the quality of the water and the economy of the region that is based primarily on agriculture and tourism which in recent years has undergone considerable development.

The study of the salinity of water by the chemical approach (Cl-, Br-) and isotopic (18O and 2H) reveal that the high salinities are related to a marine influence (proximity of the coastline: salt wedge, aerosols and sea spray), and to the leaching of the underlying evaporitic formations.

Keywords : Sahel El Haouzia, salinity, water table, salt wedge, isotope

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