METHODS IN KARST HYDROGEOLOGY (IAH INTERNATIONAL CONTRIBUTIONS TO HYDROGEOLOGY) pdf

1: Methods In Karst Hydrogeology Book â€“ PDF Download

IAH - International Contributions to Hydrogeology The International Association of Hydrogeologists (IAH) serves scientists, engineers and other professionals working in the field of groundwater resource planning, management and protection.

Groundwater is not only more abundant than surface water, but the geological environment also provides some degree of natural protection against contamination. Therefore, the exploitation and wise management of groundwater resources represents a key step towards achieving this goal. In many areas of the world, karstified carbonate rock formations hold important groundwater resources that are vital for the freshwater supply of many regions and big cities. Although the natural quality of this groundwater is often excellent, karst aquifers are more vulnerable to contamination than other aquifer types. Therefore, karst aquifers require special protection. At the same time, karst aquifers have unique hydrogeological characteristics, such as the presence of conduits, which allow groundwater to flow rapidly over large distances. Because of their specific nature, karst aquifers also require specifically adapted investigation methods. This is the first textbook that provides an introduction to various groups of methods that can be applied to study karst aquifer systems. It was written by an international team of 21 authors from 8 countries, including scientists and practitioners: We are grateful to all authors who contributed with their specific expertise to the chapters of our book. Working on this book was not always an easy task and it took a long time until the work was accomplished, but it was an honour and pleasure for us to collaborate with this distinguished group of experts. Bechtel, University of Pennsylvania and Enviroscan, Inc. Studying karst aquifers is not only scientifically challenging, but it is also important for humanity. Although this number is probably an over-estimate, karst groundwater constitutes a crucial freshwater resource for many countries, regions and cities around the world. Bakalowicz noted that karst waters are often avoided as a resource if possible because of the perceived difficulties in exploitation and their high vulnerability. For example, around the Mediterranean, karst water resources are still under-exploited, and huge quantities of potential drinking water drain via submarine springs into the sea, even in regions with a shortage of freshwater. However, karst waters can be developed if general rules, specific to karst, are followed. The techniques presented in this book can assist in better exploiting and protecting these resources. The book is intended to be useful for practitioners dealing with karst groundwater resources, their protection, management and exploitations. Also postgraduate students, PhD students and senior scientists doing their research in the field of karst hydrogeology will find much useful information about available techniques. The methods presented range from basic to sophisticated, so that the reader can select techniques that are adapted to the purpose, and to the availability of time, technical and human resources. The methods described can be used for a wide range of applications, such as the delineation of spring catchment areas, the siting of pumping wells, the monitoring of water quality, the assessment and resolution of chemical and microbial contamination problems, and vulnerability mapping. Problems related to karst and groundwater may also arise during construction works such as tunnels or reservoirs. Although this book does not specifically deal with engineering aspects as this is done in other books e. The techniques described in this book are also useful for scientific studies that aim to achieve a better understanding of water movement and the behaviour and transport of matter 2 Nico Goldscheider et al. It is hoped that the book will also provide a basis for scientists and technicians working on the development of new and better investigative methods â€" and there is still much to do! Of course, much more can be said about each method than can be done within the framework of this book. Another goal of this book is thus to provide useful references for further reading. These and other books e. Bonacci , Dreybrodt , Klimchouk et al. Some important characteristics that distinguish karst aquifers from other aquifers and hence require particular methods for their investigation are highlighted in the following paragraphs. The orientation and extension of the flow system and conduit network may change with time; conduits may collapse or be filled with sediments; saturated phreatic conduits may transform into unsaturated vadose conduits or vice versa. The importance of this temporal evolution in practical terms is particularly evident in coastal karst systems, where lower sea levels in the past may have initiated the formation of a karst drainage system that is far below the present sea level but which may still be partly active. In more general terms, the temporal evolution of karst aquifers means that there may be unexpected groundwater flow paths and drainage outlet points, which cannot be predicted on the basis of the present topographic and hydrologic setting. Taking into account landscape history during hydrogeological investigations can help to predict such flow paths and drainage points, which is crucial, for example, in establishing appropriate spatial sampling strategies. Groundwater flow may occur in large quantities in conduits and caves, yet there may be massive, unproductive rock only a few metres away Fig. Heterogeneity is a major issue in karst hydrogeological investigations. On one hand, there are techniques that aim to identify this heterogeneity, such as geophysical methods that allow potentially water-bearing fractures or conduits to be localised. On the other hand, heterogeneity also means that all types of interpolation and extrapolation are problematical if not impossible in karst. In particular, it is difficult to draw potentiometric Introduction 3 Figure 1. Schematic illustration of a heterogeneous karst aquifer system characterised by a duality of recharge allogenic vs. Other methods, such as tracer tests, are thus often more appropriate to determine flow direction and velocity. The hydraulic conductivity determined in rock samples is often very low and is mainly determined by pores and micro-fractures. Pumping tests sample larger rock volumes and thus often give higher conductivity values, reflecting the influence of macro-fractures. Finally, the behaviour of the entire aquifer system reflects the very high conductivity of the conduit network Kiraly The practical consequences are apparent: The hydraulic behaviour of the entire karst aquifer is strongly influenced by the presence of solutionally enlarged fractures and conduits. Numerical models of karst aquifers thus need to include specific high-conductivity elements that represent the conduits and lower-conductivity elements that represent the less karstified rock volumes. Allogenic recharge often infiltrates via swallow holes, while 4 Nico Goldscheider et al. Other aquifer types, particularly granular aquifers, mainly receive autogenic and diffuse recharge, while the described duality is specific for karst. The allogenic part of the catchment area always needs to be considered as well, both for water balance estimations, and for question related to groundwater protection and vulnerability. Point recharge via swallow holes is a major pathway for contaminants. Conduits may range from cm-wide solutionally enlarged fractures to huge cave passages. Therefore, karst aquifers can be described as a network of conduits embedded in, and interacting with, a matrix of less karstified rock Fig. However, water storage in the conduits is often limited often a small percentage of the aquifer volume , while significant storage may occur in the matrix, and in other parts of the system, like the epikarst. Consequently, all karst hydrogeological studies need to consider the conduits. Speleological surveys make it possible to directly observe water flow in caves. However, accessible caves are not always present and in any case, only represent a fraction of the total conduit network, mostly the inactive part, while tracer tests allow flow and transport to be studied also in the non-accessible but active parts of the network. The karst water table may rise rapidly often within hours and dramatically sometimes more than m ; the discharge of karst springs may also vary through several orders of magnitude within a short space of time. Likewise, the water and quality may display a dramatic variability, for example, in the content of suspended mineral particles, organic carbon and bacteria, including pathogens. Flow routes and relative discharges may be stage dependent to a much greater degree than in other rocks. This temporal variability requires specially adapted sampling and monitoring strategies. For example, it is inadequate to assess karst groundwater quality on the basis of water samples that are taken at regular, widely spaced time intervals. Instead, event-based sampling strategies need to be employed, i. For the same reason, continuous monitoring devices are particularly useful in karst systems: Introduction 5 Figure 1. Diving expedition in a water supply karst spring in Florida. The divers carry a cave radio below , and a team at the surface follows their route using a receiver above. The cavers re-emerged at a trash filled sinkhole. Several lessons can be learned from this example: In fact, speleological techniques are the only group of methods that are specific for karst. All other methods presented in this book can also be applied to other hydrogeological environments but may require specific adaptations when applied to karst â€” or the other way round: For example, tracing techniques, were first applied in karst flow systems, where they are still the most powerful tools to identify underground connections. Nowadays, they are 6 Nico Goldscheider et al. Other methods, like pumping tests and piezometric maps, work very well in granular aquifers, but the heterogeneity of karst often limits the application of such approaches. However, some karst aquifers are only accessible via wells and piezometers, which can yield valuable information when the experimental and interpretation techniques are adapted accordingly. The groups of methods that are available to study karst hydrogeological systems correspond to the main chapters of this book. The geological framework defines the external limits and internal structure of an aquifer and thus always needs to be considered when studying karst hydrogeology. Geomorphological observations can also deliver information concerning the groundwater flow system. Speleological investigations make it possible to study the conduit network, and to directly monitor and sample dripping waters and groundwater Fig. All other methods presented in this book can also be applied inside caves, e. However, caves are not always present or have not been explored and are usually not representative for the entire system. Hydrological techniques essentially aim at characterising and quantifying recharge into, flow within, and discharge from karst aquifers, i. Due to the high temporal variability of karst systems, special adaptations are necessary. Hydraulic techniques include the construction of piezometric maps and hydraulic tests in wells. As mentioned above, due to the specific characteristics of karst, such methods require special care and adaptations when applied to karst. However, especially in confined aquifers or coastal aquifers without accessible springs, such techniques may be a preferred choice. Hydrochemical and microbiological investigations are primarily done to assess water quality and study contamination problems. However, hydrochemical parameters can also be used as natural tracers for the origin of the water, residence times, water-rock interactions, and mixing. The monitoring techniques employed need to be adapted to the high variability of karst waters. Isotopic parameters can also be used as natural tracers. They may provide valuable additional information on the altitude of the recharge area, the origin of the water, groundwater age and residence times, and much other information. Isotopic techniques are particularly useful when they are combined with hydrochemical and tracing techniques. Tracer tests using fluorescent dyes or other substances are often the only method that is able to provide clear and detailed evidence about underground connections in karst groundwater flow systems. Tracer tests are indispensable to delineate spring catchment areas and to study all type of flow and transport processes. Geophysical techniques make it possible to see into the earth without digging or drilling but can also be applied in boreholes. In karst hydrogeology, such techniques are particularly useful to identify fracture zones and other structures below a sediment cover, and to localise appropriate sites to drill pumping wells. Geophysics can also be used for many other investigations, such as determining overburden thickness, which is crucial for vulnerability assessment. Although most geophysical methods can also be applied to other environments, the localisation of conduits by microgravity or other techniques, such as cave radio Fig.

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2: WHAT IS KARST? - Commission on Karst Hydrogeology

Methods in Karst Hydrogeology: IAH: International Contributions to Hydrogeology, 26 - CRC Press Book The importance of investigating karstified aquifers lies in their significance as a major source of drinking water.

Taking into consideration structures and hydrodynamic properties, there are: Karst aquifers form by flowing water containing carbon dioxide CO2 which dissolves carbonate rocks. Therefore, there is a close relation between aquifer evolution, the formation of caves speleogenesis and groundwater flow. Although there are many similarities among different karst systems, every karst system is also a special case and generalisation is difficult. The properties of karst aquifers greatly vary in space. There may be large quantities of water in a cave, but a borehole a few metres away may be completely dry. The aquifer hydraulic properties depend on the orientation of geologic fabric elements; for example, the hydraulic conductivity is typically high in the direction of large fractures and conduits, but may be low in other directions. Recharge water may originate from the karst area itself autogenic recharge or from adjacent non-karstic areas allogenic recharge. Duality of porosity and flow: There are two or even three types of porosity in karst aquifers: Whereas groundwater flow in the matrix and small fissures is typically slow and laminar, flow in karst conduits caves is often fast and turbulent. The water table in karst aquifers can sometimes fluctuate 10s or even s of metres in short periods of time, and karst springs typically show rapid variations of discharge and water quality. These are the typical karst areas with characteristic surface and subsurface features. Karst where it extends to considerable depths below base level. Recommended references for further reading: Hydrogeol J 18 6: Hydrogeol J 23 7: The lithology, stratigraphy, fracturing, fault pattern and fold structures are crucial to understanding groundwater flow in karst aquifers. Conduits and underground channels are crucial for groundwater flow in karst aquifers. Caves make it possible to enter the aquifer and directly observe and study a part of the conduit-channel network. Due to the high variability of flow rates of sinking streams, cave streams and karst springs, continuous monitoring of water quantity and quality is crucial in karst hydrogeologic studies. Potentiometric maps and hydraulic tests in boreholes and wells are widely applied in hydrogeology but require specific adaptations when applied to karst. Stable and radioactive isotopes can help to identify the origin of the water, determine transit times, and characterise mixing processes. Geophysics can help identify locations for well drilling, investigate subsurface cavities potential sinkholes and obtain other information on the aquifer structure. Mathematical models can help to better understand speleogenesis, flow and transport in karst aquifers. However, there are examples e. Figure 9 where the application of conventional groundwater flow models in karst environments produced catastrophically wrong results and resulted in delineation of grossly inadequate source protection zones, leading to disease outbreaks, all because the specific nature of karst was ignored. The mineral components of karst waters depend upon the composition of the rocks through which water is percolating: Hydrocarbonate HCO3 â€” calcium Ca type of waters is created from the dissolution of calcium carbonate which is a dominant type of water in limestone, while the hydrocarbonate HCO3 â€” magnesium Mg type of groundwater is present to a lesser extent, and is regularly connected to dolomitic rocks. Langmuir Physical and chemical characteristics of carbonate water, listed processes which control and influence the quality of groundwater before it reaches the spring site or well head. These processes are as follows: The composition of the infiltrated atmospheric precipitation; Evapotranspiration losses from groundwater recharge and shallow groundwaters; The acidity and degree of of undersaturation of groundwater recharge; The availability and solubility of carbonate and associated rocks, including halite, gypsum and anhydrite; Rates of solution of the rocks and contact time; Hydrologic processes such as dilution by fresh water recharge and mixing of dissimilar groundwater; Anthropogenic processes, including groundwater pollution by wastes and leachates from solid wastes. It is almost a rule that groundwater in open karst structures is low mineralized which is a result of the intensive water exchange and rapid filtration. In deeper parts of the aquifer, slower filtration results in an increase in mineralization. This variation is often minimal, but nevertheless indicates a certain differentiation that may be important under specific circumstances e. Therefore, in the case of carbonate karst the quality of natural karst waters is excellent almost by definition: But if pollution sources are present in the catchment of an unconfined karstic aquifer then severe hazards follow. The situation is even more complicated, however, when we deal with a non-homogenous and anisotropic aquifer such as karst: We may distinguish the two main kinds of tapping groundwater in karst: Tapping karstic groundwater flow at discharge points â€" springs Figure Tapping karstic groundwater flow within the aquifer catchment â€" artificial structures such as wells, galleries or other similar structures Figure Groundwater is tapped not only to exploit it for drinking, industrial, heat extraction, or irrigation purposes, but also for dewatering in the case of mine pits, urban areas or cultivated land which should be protected from a high groundwater table. Use for different purposes The karstic springs are widely utilized as a source of drinking water supply. Many countries utilize karstic springs simply because there are no other alternatives, but in many other countries awareness of their importance and the good water quality they provide is a principal factor for such a decision. The karstic aquifers have a significant proportion of the water supply in the following regions: Natural drainage of aquifers through springs can cover water demands on a wide scale: Although the latter is not a big problem in terms of amount of water, for the big consumer a very large aquifer and spring discharge are required. There is a wide range of uses of karstic waters. In arid regions in the Near East and Middle East it is, for instance, very common to tap karstic springs and to construct gravity channels for irrigating arable land. Springwater is also widely used for watering animals, and fresh water of good quality provides security for animal health and growth. The use of karstic waters in hydropower generation by utilizing high hydraulic head is limited mostly to the Alps Austria, Switzerland , while thermal properties of karstic waters and springs are utilized elsewhere. Bakalowicz M Karst Groundwater: A Challenge for New Resources. Springer-Verlag, Berlin, pp. Burger A, Dubertret L eds Hydrogeology of karstic terrains. Impacts, Consequences and Implications. Balkema, Rotterdam, pp. Goldscheider N, Drew D Eds. Engineering, Theory, Management and Sustainability. BH, Amsterdam, pp. Kresic N Water in Karst. Management, Vulnerability and Restoration. McGraw Hill, New York, pp. Natural and Anthropogenic Hazards in Karst Areas: Recognition, Analysis and Mitigation.

3: Karst Hydrogeology Book â€“ PDF Download

*Methods in Karst Hydrogeology: IAH: International Contributions to Hydrogeology, 26 [Nico Goldscheider, David Drew] on www.enganchecubano.com *FREE* shipping on qualifying offers. The importance of investigating karstified aquifers lies in their significance as a major source of drinking water.*

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5: IAH - International Contributions to Hydrogeology - Routledge

INTERNATIONAL CONTRIBUTIONS TO HYDROGEOLOGY 26 Editor-in-Chief, IAH Book Series British Geological Survey Wallingford, UK. Methods in Karst Hydrogeology.

6: Publications - Commission on Karst Hydrogeology

The XXXII IAH (International Association of Hydrogeologists) and VI ALHSUD (Latin-American Association of Groundwater Hydrology for Development) Congress on Groundwater and Human Development, held in , in Mar del Plata (Argentina), brought together over participants from more than 40 countries.

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7: The International Association of Hydrogeologists - IAH / AIH

IAH International Contributions to Hydrogeology ("blue" book series) Volume Year Theme 1 Hydrogeology of karst terrains: case histories1,2 2 Hydrogeology of limestone terranes: annotated bibliography of carbonate rocks, volume 31,2.

8: Methods in Karst Hydrogeology : David Drew :

METHODS IN KARST HYDROGEOLOGY INTERNATIONAL CONTRIBUTIONS TO HYDROGEOLOGY 26 Series Editor: Dr. Nick S. Robins Editor-in-Chief, IAH Book Series.

9: CRC Press Online - Series: IAH - International Contributions to Hydrogeology

IAH - International Contributions to Hydrogeology About the Series The International Association of Hydrogeologists (IAH) serves scientists, engineers and other professionals working in the field of groundwater resource planning, management and protection.

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