Goldschmidt 2022 Abstract
https://doi.org/10.46427/gold2022.12504

Buried paleo-channel identification via dissolved atmospheric noble gases and preferred anisotropy pilot point inversion

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We present an efficient method for the detection of buried paleo-channels in alluvial sand and gravel (ASG) aquifers. Buried paleo-channels in ASG aquifers are typically highly conductive for groundwater flow and responsible for preferential flow paths capable of transporting contaminants faster than the surrounding sediments. However, it is notoriously difficult to detect and reproduce buried paleo-channel like connected structures of increased hydraulic conductivity with commonly used techniques. Consequently, these anisotropic structures are rarely considered in the delineation of wellhead protection zones and the models used for groundwater management. To alleviate this problem, we propose a new framework based on a combination of hydraulic and tracer-based measurements and subsequent calibration of a fully coupled surface water-groundwater model against these observations. Tracer-based observations consist of radioactive tracers (^{222}Rn, ^{37}Ar, $^{3}H/^{3}He$), which allow characterization of groundwater residence times, and of atmospheric noble gases, which allow tracking recently infiltrated river water through an ASG aquifer. Calibration is based on an innovative pilot point inversion that considers the spatially-varying directionality of the alluvial sediments and facilitates the identification of buried paleo-channel like connected structures. The proposed approach is more efficient compared to other existing methods for paleo-channel detection, as complex and often poorly constrained geostatistical simulations are not required. The applicability framework is demonstrated on a real-world wellfield in an ASG aquifer in Switzerland.