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CONSTRAINTS ON THE PERMEABILITY STRUCTURE OF ALLUVIAL AQUIFERS BASED ON THE PORO-ELASTIC INVERSION OF MULTI-FREQUENCY P-WAVE SONIC

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Summary. Knowledge of the permeability distribution is a key prerequisite for reliable predictions of fluid flow and contaminant transport and thus critical for the effective protection, remediation, and sustainable management of the world's increasingly scarce and fragile groundwater resources. Geophysical constraints with regard to the permeability structure are particularly valuable not only because they are comparatively cheap and non-invasive in nature, but also because they have the potential to bridge the inherent gaps in terms of resolution and coverage that exist between traditional hydrological methods. Although standard geophysical exploration approaches cannot provide any direct information on the permeability of the probed medium, there are less conventional techniques that exhibit some more or less direct sensitivity to this parameter. To this end, we have explored the possibility of constraining the permeability structure of surficial alluvial aquifers based on the poro-elastic inversion of the P-wave velocity dispersion inferred from borehole sonic log measurements. Modern sonic logging tools designed for shallow environmental and engineering applications allow for P-wave phase velocity measurements at multiple source frequencies over a bandwidth covering 5 to 10 octaves. Methodological considerations indicate that, for saturated unconsolidated sediments in the silt to sand range and typical source frequencies ranging from approximately 1 to 30 kHz, the observable P-wave velocity dispersion is sufficiently pronounced to allow for reliable first-order estimations of the underlying permeability structure based on the theoretical foundation of poro-elastic wave propagation. These predictions have been tested on and verified for a typical surficial alluvial aquifer. In doing so, we have paid particular attention to exploring and constraining the potential impacts of poorly constrained parameters in the governing equations on the corresponding permeability estimates. Our results indicate that the thus obtained permeability estimates as well as their variabilities within the pertinent lithological units are remarkably close to those expected based on the corresponding granulometric characteristics.