EGU21-4338
https://doi.org/10.5194/egusphere-egu21-4338
EGU General Assembly 2021


# A transient backward erosion piping model based on laminar flow transport equations

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Backward erosion piping (BEP) has been proven to be one of the main failure mechanisms of water-retaining structures worldwide. Dikes, which are often built on sandy aquifers, are particularly vulnerable to this special type of internal erosion. In this research, we propose a numerical solution that combines a 2D Darcy groundwater solution with Exner's 1D sediment transport mass conservation equation. The inclusion of criteria for incipient particle motion, as well as the linkage of the bedload transport rate to the pipe progression, enables us to build a stable time-dependent piping model. As an estimate of sediment transport, we tested four different empirical transport equations for laminar flow. The model performance was evaluated based on the results of a real-scale dike failure experiment. Through this, we were able to demonstrate the applicability of existing sediment transport equations to the description of particle motion during piping erosion. The proposed transient piping model not only predicts the pipe progression in time, it also allows for an identification of pore pressure transitions due to the erosion process. The main finding of the study is that from the four different modeling approaches for laminar flow, it is recommended to follow the approach of Yalin et al. (1963, 1979) to simulate backward erosion piping in dikes.