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A comparison of falling head vs constant head percolation tests using field results and numerical modeling to determine the hydraulic conductivity of soils

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The infiltration capacity of soil across varying states of saturation in the vadose zone is critical intelligence required for many approaches taken in hydrological catchment modelling. Such knowledge is also essential in order to design effective engineered systems that rely on the percolation of water and/or wastewater as a key part of the overall treatment process; for example solutions for on-site wastewater treatment and storm water runoff systems as an option increasingly chosen within SUDS (sustainable urban drainage systems). Such treatment systems, which are often passive in nature, are increasingly seen as appropriate sustainable solutions, which aim to attenuate both hydraulic and pollutant loads in order to protect surface and groundwater resources. Several different approaches can be taken to determine a soil's hydraulic conductivity, either using percolation tests (carried out in the laboratory or in the field) or via soil size distribution. Each method yields different estimates of (saturated) hydraulic conductivity which can then be combined with knowledge of soil moisture retention curves, from which predictions can then be made of water flow under transient unsaturated conditions using, for example, the commonly adopted Richards equation.

This research has evaluated results from over 800 field tests carried out across a range of different subsoil types in Ireland. These tests were falling head percolation tests used to assess whether a site is suitable for an on-site wastewater treatment process for new developments in areas which lack access to centralised wastewater treatment systems. Falling head percolation tests are widely used as they are relatively easy to carry out, but suffer from lack of rigorous, standardised conditions during the test and so prove challenging when trying to convert the results into a rigorous metric that can be used for infiltration design. These results were therefore compared at selected sites, across the range of soil textures, against more rigorous fixed head permeameter tests.

The data from the water each percolation test (water level drop and/or volume infiltrated) has then been modelled using 2-D numerical modelling code (Hydrus 2D) to derive saturated hydraulic conductivity values (Ks). In order to simulate a falling head percolation test the software code needed to be tailored whereby a seepage face boundary condition at edge of test hole was included, using a modified "well" boundary condition. The relationship between the field derived falling head saturated hydraulic conductivity results (Ksat) against the model derived Ks values has been plotted across the range of soil textural classes from fast percolating sandy soils to very slow clayey soils. Equally, the same comparison has been made between Ksat from the field permeameter tests against the model derived Ks values. This has therefore allowed direct comparison to be made between the two field methods via the same numerical modelling approach, revealing significant differences in predicted Ks for the same soil types depending on which field test is used. In general, the permeameter method seems to estimate higher hydraulic conductivity values compared to the falling head method, which needs to considered in future modeling and design applications.