

# Paradoxes and Realities in Unsaturated Flow Theory

WILLIAM G. GRAY

*Department of Civil Engineering, University of Notre Dame, Notre Dame, Indiana*

S. MAJID HASSANIZADEH

*National Institute of Public Health and Environmental Protection, Bilthoven, Netherlands*

In currently applied theory of unsaturated flow, paradoxes exist concerning the equation of state for the water phase, the idea of a water phase at negative absolute pressure, the applicability of the hydrostatic pressure gradient at equilibrium, and the lack of explicit inclusion of interface effects in the problem formulation. The theory of unsaturated flow presented here eliminates those paradoxes and indicates that the hysteresis in capillary pressure and relative permeability may be accounted for by allowing these quantities to depend on interfacial area as well as saturation. The wettability potential is shown to be a thermodynamic function which is important in describing unsaturated flow processes. The momentum balance equation for the interface between the air and water phases also contributes to a systematic and tractable set of equations which describe unsaturated flow.