EFFICIENT APPROACH TO SOLVING TRANSIENT UNSATURATED FLOW PROBLEMS. II: NUMERICAL SOLUTIONS

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Abstract: Although the finite-difference method (FDM) has been commonly used to numerically solve Richard's equation, numerical difficulties are often encountered, even for comparatively simple problems. To minimize convergence problems, comparatively small discretization and time steps have often been adopted to solve this highly nonlinear equation, resulting in significant computational costs. To overcome these difficulties, this paper presents an efficient approach to solving Richard's equation that combines two numerical techniques: the FDM and the cubic interpolated pseudoparticle (CIP) method. The FDM is used to solving the diffusive flow component of Richard's equation, the convergence of which can be controlled by adopting time steps corresponding to Neumann's number under 0.5. In contrast, the CIP method is used to solve the advective flow component of the equation. The CIP method is found to be particularly suitable for facilitating convergence and eliminating the presence of spurious results when the Courant number is under 1.0. Analytical solutions for transient unsaturated flow problems, developed in a companion paper, allow comparison between the predictions obtained using the proposed numerical approach and the exact solutions. Use of the newly developed algorithm is found to be particularly accurate and stable for solving Richard's equation, being clearly superior to the use of the traditional FDM. After validating the new numerical approach using the boundary conditions and hydraulic functions for which analytical solutions have been developed, the new numerical scheme was subsequently implemented to address more general unsaturated flow problems. In particular, the new numerical approach was extended to solve unsaturated flow problems involving complex soil hydraulic functions as well as different boundary conditions. Comparisons are presented to illustrate the accuracy of the new numerical approach even when extended to incorporate the use of complex hydraulic functions for which there are no analytical solutions. The efficient, validated numerical schemes presented in this paper are found to be well suited for solving complex unsaturated flow problems.

Full reference:

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