Modelling Variably Saturated Flow with HYDRUS-2D. D. RASSAM, J. SIMUNEK, and M.TH. VAN GENUCHTEN. ND Consult, Brisbane, Australia. 2003. Paperback plus CD-ROM. $80.00. ISBN 0-646-42309-6.

The highly nonlinear character of flow through partially saturated porous media has created great obstacles to development of accurate and accessible solutions to practical problems. This in large part explains the continued popularity of the rather drastic and obsolete approximations, such as those of Green and Ampt. Being personally familiar with the generic aspects responsible for the lack of stable codes to solve unsaturated flow problems and having studied macropore and fingered flow, I was skeptical of HYDRUS-2D when I met Dr. Simunek for the first time in the early 1990s. However, the stunningly accessible interface and the remarkable stability of the code quickly won me over, and I adopted it as a central part of my teaching and research program. When the speed of computation using HYDRUS-2D increased by a factor of 20 with the advent of the Pentium platform it was clear that this program was going to facilitate the long overdue adoption of numerical modeling within the broad community of people concerned with flow of water and solutes through porous media. Computing power is now such that HYDRUS-2D problems employing tens of thousands of nodes are entirely tractable, reflecting the visionary investment that Dr. Simunek made when computers were 1000 times less powerful than those now available.

Had HYDRUS-2D remained as it was in the mid 1990s, it would have changed the way the world viewed unsaturated soils. What was less expected, but now I see is in keeping with his personal drive for excellence, was that Dr. Simunek would relentlessly continue to expand the scope and quality of the project. Beyond simple solutions of Richards' equation, HYDRUS-2D now includes (among other features) automated soil properties estimation based on Rosetta, multiple hysteretic water retention and permeability functions, root water uptake, inverse estimation of soil properties, generation of correlated Miller-similar heterogeneity, simulation of thermal energy storage and flux, and simulation of chains of reactive solutes. HYDRUS-2D has clearly established itself as the standard tool for unsaturated flow transport modeling, the MODFLOW of variably saturated flow, to the great benefit of users.

HYDRUS-2D has consistently included a user-friendly graphical user interface and automatic time-step adjustment, making the model remarkably accessible for many scientists. Furthermore, Drs. Simunek and van Genuchten published a greatly improved 253-page manual for the program with the version that shipped with version 2.0 in 1999. This 1999 manual suffers from being written by the authors of the model, frequently losing sight of what might not be obvious to the user. Thus, the flexibility of the program, combined with the very technical nature of many of the capabilities, left many users unable to make efficient use of the program. Many times simulations would fail to run for reasons inexplicable to the user, and many of the important features of the program were not apparent. Though the dedicated practitioner might visit the very helpful discussion group for the program at www.pc-progress.cz, this does not offer a comprehensive or efficient general resource. Thus, a "How to use HYDRUS-2D" book that systematically explains how to use the program has been sorely needed. With *Modelling Variably Saturated Flow with HYDRUS-2D*" Rassam et al. (2003) answer this need admirably (http://typhoon.mines.edu/software/igwmcsoft/hydrus_book.htm).

The approximately 270-page text is published in a large soft-bound format with many color figures and is richly illustrated with example screens and plots of model output. The printed information is complemented by a CD-ROM with 107 example problems spanning most of the water movement issues that could be addressed by the program. The text is organized in a logical sequence: operational issues of the file management structure, preprocessing, and postprocessing features. The text then delves into some of the specific features of the program pertinent to water movement, with separate sections dealing specifically with root water uptake, and inverse solutions. It should be noted that this book does not attempt to be comprehensive in its treatment, rather focusing specifically on the movement of water, while avoiding discussion of the program's considerable solute and heat transport features. The cursory eight-page appendix devoted to the complex and often confusing solute transport components of HYDRUS-2D introduce the bare essentials, but will do little to assist the serious user with questions of units, confusing descriptions of isotherms, and frequent spatial instabilities in the solutions. The heat transport capabilities are not even mentioned, which I believe was an unfortunate omission given that it could have been treated quite adequately in a few pages. It should be noted that in using HYDRUS-2D the heat flow module is not nearly as problematic as that of solutes, so the alert user will be capable of making use of these features without undue difficulty.

Having used HYDRUS-2D for almost a decade, I was very impressed that Rassam et al. (2003) were able to guide the new user and teach an old dog new tricks. Previously, I had not known how to use the very useful steady-state condition finder and the rhomboid selection option, and I had not seen the details of how to run batch files. The trouble-shooting appears to be well informed by the years of communication with users, and catches the vast majority of common problems. There is one bug that the book does not address that merits mention. The program will let you assemble line segments to form the boundary of a problem, will correctly generate the mesh, and allow the user to ascribe conditions. However, when you go to run this problem it will crash with a floating point error. Why? To the best of my knowledge this is due to assigning two boundary nodes to each point where the line segments join. This is a problem that needs attention and I wish had been addressed in the book, since this problem catches about 25% of my students who use the code.

The bottom line is that this is an outstanding companion for any HYDRUS-2D user. The authors have presented this often complex subject in an easily understood manner. HYDRUS-2D continues to be a mainstay for unsaturated flow modeling and with this publication has become even more useful.

John Selker
Bioengineering
Oregon State University
Corvallis, OR 97331-3906
(selkerj@engr.orst.edu)

Published in Vadose Zone Journal 3:725 (2004).

677 S. Segoe Rd., Madison, WI 53711 USA