Lawrence Berkeley National Laboratory

Recent Work

Title
PHYSICAL ASPECTS OF THE INTERFACE BETWEEN THE SATURATED AND THE UNSATURATED REGIMES

Permalink
https://escholarship.org/uc/item/3904p0x3

Author
Narasimhan, T.N.

Publication Date
1980-07-01
To be presented at the American Geophysical Union Chapman Conference on Subsurface Contributions to Stream Flow, University of New Hampshire, Durham, NH, October 5-9, 1980

PHYSICAL ASPECTS OF THE INTERFACE BETWEEN THE SATURATED AND THE UNSATURATED REGIMES

T. N. Narasimhan

July 1980

Prepared for the U.S. Department of Energy under Contract W-7405-ENG-48

TWO-WEEK LOAN COPY

This is a Library Circulating Copy which may be borrowed for two weeks. For a personal retention copy, call Tech. Info. Division, Ext. 6782
PHYSICAL ASPECTS OF THE INTERFACE BETWEEN 
THE SATURATED AND THE UNSATURATED REGIMES

T. N. Narasimhan
Earth Sciences Division
Lawrence Berkeley Laboratory
Berkeley, California 94720

Perhaps the most important physical processes that govern our ability to 
quantify groundwater-stream flow relationships are those related to the tran­
sition between the saturated and the unsaturated regimes. Traditionally,
this has been a gray area caught between, on the one hand, the saturated zone 
of soil mechanicians and hydrogeologists (who are mainly concerned with flow 
in the saturated material) and, on the other hand, the unsaturated zone of 
soil physicists, soil chemists, and agricultural engineers (who are principal­
ly concerned with soil-plant interactions). The principal physical phenomenon 
that distinguishes the two regimes is the mechanism of storage. Thus, while 
the saturated regime is governed dominantly by the compressibility of the por­
ous matrix (with minor influence from water expansion), the unsaturated zone 
is dominated by desaturation.

Concentrating on effects of first-order magnitudes, soil engineers and 
hydrogeologists have rightly ignored the quantity of water moving within the 
unsaturated zone. A result of this approach has been the free surface approx­
imation, which is really a mathematical convenience rather than physical reality. Similarly, soil physicists and agricultural engineers have mostly 
ignored matrix deformation in partially saturated soils. An upshot of this 
approach is that within the capillary zone (that is, when moisture suction 
lies between air-entry value and atmospheric pressure), soil moisture diffu­sivity becomes infinite. Also, when required to consider the saturated zone 
in addition to the unsaturated zone, there has been a tendency to treat the 
saturated regime as a steady-state flow regime (obeying the Laplace equation) 
while the partially saturated regime is considered as a transient domain 
obeying the parabolic equation).

From a conceptual sense, as well as from a practical need to rationally 
handle realistic field problems of increasing complexity, there is a need to 
unify saturated-unsaturated flow in a realistic fashion. A key factor in 
this regard is the extension of matrix deformation into the partially satura­
ated regime. This requires an appropriate constitutive relation between 
moisture suction and skeletal stresses. Additionally, in certain cases of 
high saturation where air bubbles may exsolve from the water, it may be
necessary to treat the flow regime as a multiphase system rather than one of simplified unsaturated-saturated flow.

Despite the computing power that is currently available, it is still not economical to apply the general saturated-unsaturated flow equation to field problems such as those relating to even small watersheds. This is because the nonlinearities relating to permeability and moisture capacity are so pronounced in partially saturated materials that a very fine partition of the flow region is essential if one requires to minimize integration errors. The practical way out in such cases is to use judicious computational assumptions in order to obtain solutions. Nonetheless, it is important that the physical bases of the field problem are understood in as complete a fashion as is possible before imposing the badly needed assumptions.

This work was supported by the U. S. Department of Energy under Contract W-7405-ENG-48.
This report was done with support from the United States Energy Research and Development Administration. Any conclusions or opinions expressed in this report represent solely those of the author(s) and not necessarily those of The Regents of the University of California, the Lawrence Berkeley Laboratory or the United States Energy Research and Development Administration.