SCHOOL OF DOCTORAL STUDIES IN ENVIRONMENTAL ENGINEERING - XIX cycle

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Subsurface Flow Modelling at the Hillslope Scale: Numerical and Physical Analysis

Abstract of the doctoral thesis

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The importance of subsurface flow in hillslope hydrology has been widely demonstrated in the past twenty years. Neal and Rosier (1990), Sklash (1990), McGlynn (2003), McDonnell (2003), Kirchner (2003) and many others demonstrated through field monitored experiments that the most part of the hillslopes runoff production comes from the subsurface, reaching often percentages around 80% of total runoff. Furthermore they found that the subsurface flow is mainly made of old water previously stored within the catchment slopes.

Torres (1998), Pierson (1980) and others evidenced that catchment subsurface runoff response time could be very fast especially for wetter ground moisture contents. Nevertheless Fiori (2006), Kumar (2004), Montanari et al. (2004), Bertoldi et al. (2006) and many others highlighted that the capability of the actual modelling techniques of predicting the temporal scales of subsurface hillslope hydrology response is very poor and in order to get good results they require the use of overestimated soil hydraulic parameters.

Furthermore the uncertainties and the variability of such parameters exert indeed a crucial role and require then a deep analysis in order to highlight their effects in modelling accuracy. Nonetheless the equations for saturated and unsaturated flow modelling sometimes do not describe with great precision the physical processes that are instead highlighted in many experimental works, and this is to be imputed to all the constitutive laws employed within them (Hassanizadeh, 1993; Shultze, 1999; Germann, 1999; Torres, 2001; and many others).

Therefore the modelling of subsurface processes requires great care and attention and the work done in this thesis focuses on some aspects related to this problem.

The objectives of this work are to investigate some features connected to subsurface flow. First of all an extensive analysis of the most used numerical schemes on convergence and on the influence of heterogeneous hydraulic parameter fields in their behaviour in both flow and transport is achieved. We have seen that the most classical method have a more robust structure than new postprocessing schemes that are aimed at improving the classical solutions. The performed studies revealed the importance of being aware of how we are solving the equations and how they deal with the domain features, that are hydraulic parameters, in order to be conscious that the numerical solution might fail to predict correctly the processes we want to model and to give the correct weight to modelling uncertainties.

The second important point regards the use of constitutive laws in the governing equations which can have a great drawback on the modelling problems exposed above. The analysis on the validity of such physical constitutive laws employed in saturated and in non saturated flow equations is done. In particular the validity of Darcy law in non stationary flow fields in both saturated and unsaturated media is done as well as the

comparison with solutions achieved with the more general momentum balance equation. This is done specifically to investigate some strange soil behaviour revealed in field and laboratory based works in which the unsaturated flow showed unexpected responses (Germann, 1999; Torres, 2001; Torres, 2002).

On the basis of this study we could make our own speculations on what happens at the base of strange flow behaviour in unsaturated flow. In our opinion a kind of capillary barrier formation in non localized areas of the flow field might explain many of the evidences arisen experimentally.

We decided then to design and realize a laboratory column experiment. The work is actually ongoing and preliminary work is reported. Then discussion on our expectations and speculations around the physical processes that are poorly described by the unsaturated flow equations are then exposed.