MULTISCALE MODELING, ANALYSIS AND SIMULATION OF PREFERENTIAL FLOW
Project Summary

Ralph E. Showalter, *Principal Investigator*
Tel. 541-737-5149, FAX: 541-737-0517, show@math.oregonstate.edu
Małgorzata Peszyńska, *co-Principal Investigator*
Tel. 541-737-9847, FAX: 541-737-0517, mpesz@math.oregonstate.edu
Department of Mathematics, Oregon State University, Corvallis, OR 97331-4605

The mainstream view of flow phenomena in porous media takes into account, roughly speaking, three fixed and separate length scales. These are the pore scale, at which one recognizes the individual pore geometry and where Stokes-like models apply, the Darcy scale at which empirical Darcy and Richards models are used, and the field scale to which these models are *upscaled*. Albeit connections between models of flow in porous media at two or more scales have been explored, there exists today essentially no capability to model phenomena which occur at multiple not well separated scales and in which such scales and specific models only apply locally in space.

In this project we focus on a problem of *preferential flow in porous media* which, on one hand, has enormous importance in various applications, and which, on the other hand, presents a formidable challenge for multiscale multiphysics modeling, analysis, and numerical approximation. Preferential flow occurs in natural porous media such as soils and bedrock due to the presence of unusually large connected pores or fast flow channels. Such flow combines unsaturated and saturated flow processes; we present evidence that it cannot be accurately described by existing models even of double- or multiple-porosity type.

We propose to develop methods that *blend* the scale separation and describe processes at intermediate scales. We will model the continuum of scales from pore to Darcy scale using a "Brinkman-Forchheimer-like" approach. Second, we will refine the modeling concepts of multiple-porosity models by modifying the interface conditions and their dual exchange terms. Third, we will verify the proper scaling, equilibrium and non-equilibrium assumptions applicable to nonlinear transient models of unsaturated flow and derive dynamic upscaled models for multiscale preferential flow.

We will use rigorous *analysis* and numerical *simulation* to guide the modeling efforts; particular items include verification of well-posedness, sensitivity, (scale-)convergence, and adaptivity of *model, scale and discretization* in order to reduce the total computational modeling error. The underlying PDEs need not be of uniform structure; we allow for the models, their boundary conditions, data, and the presence or absence of couplings between models to be adapted as well. A major outcome of the research will be identification of whether and how the *tailing* effects can be truncated. We will use data from other projects and facilities, for example, we will explore the data from the unique facility Andrews Experimental Forest affiliated with OSU. We will draw upon our collaborations in order to include more relevant scales as well as uncertainty in the future continuations of this project.

The proposed research will have impact in several interconnected ways. First, the direct outcome of the project will be the enhanced understanding, improved modeling and predictive capability of the processes of preferential flow in porous media. This problem is extremely important for forest engineering, the management of waste isolation in sites such as Hanford site or Yucca Mountain and of water supply on basin scale. It can have significant local (e.g., leaking to metro channels in Washington D.C.) and regional importance. Our research will also have impact in several areas related by application or methods; these include the modeling of coupled flow and geomechanics in landslides, the understanding of *hyporheic exchange* where the interest is in the accurate modeling and development of nonlocal terms related to the river and stream flow, the modelling of blood flow, and advances in multiscale models for nuclear transport.

Second, this understanding will be disseminated and shared with students and colleagues in related application disciplines as part of our increased *educational* activities and continuing efforts to develop collaborative relationships at both local and regional levels. This process will proceed naturally at our home institution due to an existing network of formal and informal water- and applied mathematics-related collaborations at OSU and beyond. We will develop and propose expanded curriculum, train graduate students in the direction of this project and organize a workshop devoted to multiscale modeling in porous media (2006). We will continue to run a focused seminar with local and outside speakers devoted to the project themes, and we will participate in a proposed Multiscale Modeling Summer School organized by a NorthWest Consortium including researchers from Pacific Northwest National Laboratory and Washington State University.