Dynamics of subsurface flow of fluids of different densities

K. Udo Weyer
WDA Consultants Inc., Calgary, Alberta, Canada

ABSTRACT
Building an understanding of the actual physics of subsurface flow is a confusing experience at the best of times, exposing one to conflicting statements from the sides of engineers, hydrogeologists, and, for a decade or more, by the followers of free convection and density-driven flow. In case of variable density flow involving salt water and brines, the confusion is magnified. It is generally assumed that, due to their higher density, two systems of forces act upon salt water and brines, namely piezometric head forces and buoyancy forces. Presently, the buoyancy forces are always assumed to be directed vertically downwards for fluids heavier than the host fluid, or upwards for lighter fluids. These assumptions are widely applied in mathematically dominated fluid dynamics.
Hubbert (1953) has shown, however, that vertical buoyancy forces (balanced by gravitational forces) exist only in the hydrostatic case but not under hydrodynamic conditions. In the hydrodynamic case forces due to density differences are directed along the piezometric pressure potential force of the host fluid and integrated into the resultant force calculation.
Hydrostatic (no-flow) boundary conditions for mechanical forces usually exist in laboratory tests and under oceans (off-shore). Hydrodynamic subsurface flow conditions exist in on-shore areas with topographical relief.
The presentation will shed light on the maze of conflicting statements issued within mathematically-dominated engineering hydraulics and groundwater dynamics, and will help foster the understanding of the correct physics involved and how this physics can be beneficially applied to practical cases regarding subsurface flow in general, hydrodynamic migration of contaminants, variable density flow, migration of hydrocarbons and CO_2, and to scientific processes in the present and within the geological past. It will also introduce a practical field case involving the numerical modelling of variable density flow at a major industrial landfill site in Europe.