

The study of fluid flow, specifically with application to flows near the fluid-sediment interface in natural waters, has proven to be a very challenging research topic. Both numerical and physical experiments have proved challenging due to the large variability in the scale of the dynamics. Mathematically, analytical solutions have proved virtually impossible to find, except in situations that are greatly simplified. In spite of these difficulties, great progress in understanding these flows has been made over the last few decades. My area of research has focused on understanding sediment pickup in lake bed dynamics and the flow in porous sediments.

Much of the current theory of sediment resuspension and flow in porous sediments is centred on two major driving processes: surface gravity wave induced pressure fluctuations acting on the lake bottom, and temperature gradient induced convection (sometimes referred to as the "convective turnover pump"). However, surface gravity wave induced pressure profiles are negligible for lakes of depth greater than a few meters, and temperature induced pumping is only generated during portions of the transition seasons (autumn and spring). We have shown that internal waves, or waves in the interior of lakes, can provide a mechanism for both sediment resuspension and for driving flow through porous sediments. In particular, we have proposed a model in which internal wave induced turbulence unplugs pores clogged by detritus. This in turn allows for greatly enhanced exchange of fluid between the porous bottom and the main water column, with consequences for a variety of biogeochemical cycles, and through these, on lake ecology.

The above discussed work assumed a porous lake bed. Darcy's law provides a phenomenological equation for the seepage through the sediment layer. This is a very common assumption, which has been demonstrated to provide very good correlation with field experiments. However, much of the lake bed is not composed of sand or other porous material, and is instead composed of a layer of mud, sometimes referred to as the nepheloid layer. This layer can be modelled as a non-Newtonian fluid.

My research assumed that these fluids obeyed one of several standard models in the literature, namely either a power-law or Carreau fluid viscosity profile. In a similar vein to the research on the porous media model, we were interested in the turbulent effects on these non-Newtonian fluids. In order to simulate this problem, we developed highly accurate, pseudo-spectral software to model these fluids in several idealized configurations. We then used this software to consider several classical problems in hydrodynamic stability. For a Newtonian fluid, the Orr-Sommerfeld equation demonstrates that Poiseuille flow will go unstable at a Reynolds number of  $Re=5772$ . In the case of a non-Newtonian fluid, we discovered that this critical Reynolds number can be drastically reduced depending on the power-law parameter. In addition, the critical wavelengths at which instability sets in are also shifted. This preliminary work demonstrates that the non-Newtonian nature of the lake bed mud may be more important than previously considered. In the future this work will be extended to develop a more complete model of lake dynamics in which internal waves interact with a non-Newtonian fluid muddy layer. s

Both of the above projects involved a variety of novel numerical techniques, as well as asymptotic analysis. Moreover, both required integration of the mathematical results into the scientific literature. This second aspect is particularly difficult, but is nevertheless vital in increasing the impact of the work in the applied water quality community.