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Advances in analytical modeling of suspended sediment transport

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This state-of-the-art review describes the progress in analytical modeling of suspended sediment transport by turbulent wall shear flow. The mechanics of the suspended sediment transport by turbulent flow represented by various concepts, such as the diffusion concept, the energy concept and the stochastic concept, is appraised. The effects of sediment suspension on velocity distribution, von Kármán constant value and turbulence characteristics are highlighted. As the latest development of the subject, this paper explains the scaling law of suspended sediment concentration within the wall shear layer stemming from the energetics of turbulent eddies. This scaling law elucidates that within the wall shear layer, the suspended sediment concentration obeys a unique scaling law with the vertical distance from the bed. Finally, the modeling challenges are outlined as a future scope of research.

1. Introduction

The suspended sediment transport is a key subject of interest in fluvial hydraulics and applied hydrodynamics, because the suspended sediment transport is the primary contributing fraction to the total sediment transport in fluvial streams. It plays a vital role in governing the fluvial morphodynamics, ecological management, nutrient transport and so on. A brief description of suspended sediment transport by turbulent flow is furnished below:

When a turbulent stream flows over a loose sediment bed, the bed particles are transported in various layers depending on their modes of transport (Fig. 1). For a lower value of bed shear stress surpassing the threshold bed shear stress for the particle motion, the particles are transported within a thin contact load layer (Fig. 1). On the other hand, for a high value of bed shear stress, the near-bed turbulence is to lift up the finer particles beyond the contact load layer keeping them in suspension. By definition, the sediment particles remain in suspension when the motion of the particles is such that they are surrounded by the fluid parcel for a sufficiently long duration. The schematic of suspended sediment particles in a turbulent flow is given in Fig. 1. Note that the density of dots indicates the particle concentration. The curved arrows designate the turbulent eddies that carry the suspended particles in their core. The suspended particles are convectively transported upward triggered by the vertical velocity fluctuations and then they mix up with the surrounding fluid. The settling tendency of a sediment particle due to gravity is balanced by the upward turbulent diffusion to achieve a dynamic equilibrium. Importantly, Bagnold (1966) reported that the sediment particles are kept in suspension if the shear velocity exceeds 0.8 times the terminal fall velocity of the sediment particles. Generally, the suspended

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