Open channel flow

Open-channel flows are a special class of boundary-layer flows that are confined to a channel form.

Why are open-channel flows important?

- Many natural systems responsible for the transport of sediment are channelized, in both subaerial and subaqueous environments.
- Nearly all of the modeling performed on the entrainment and transport of sediment is either in open channels or in 1-D boundary layers.

Like any fluid mechanical problem, dimensional analysis can play a key role.

In open channel flow, there are only a few variables that are needed to describe transport. They are…

U = velocity [L/T]
L = relevant length scale [L]
μ = dynamic viscosity [M/(LT)]
ρ = density [M/L^3]
g = gravitational acceleration [L/T^2]

Different velocities (u_*, u_{max}, v, etc.) and length scales may be used (R, H, W, P). Typically if you are studying a particular set of physics, only one or two of these will be important (e.g., sediment transport is highly dependent on u_*)

Buckingham's Pi thereom states that there are *n*-*r* dimensionless Π coefficients, where *n* is the number of independent physical quantities and *r* is the number of dimensional units (i.e., M, L, T) that describe a physical system.

There are many ways to generate these two dimensionless quantities (which can generate many different forms). However, the most conventional terms are

$$Fr = \frac{U}{\sqrt{gL}} \tag{1}$$

$$Re = \frac{\rho UL}{\mu} = \frac{UL}{\nu} \tag{2}$$

Therefore, if these two dimensionless parameters can be matched, the physics of the flows should be 'similar'. The difficulty is that water has a relatively low viscosity. For instance, in a 1:100 length scale model, the viscosity has to be:

$$\nu_{mod\,el} = 10^{-3}\nu_{natural} \qquad (3)$$

Alternative… **Reynolds similarity**

The Froude number can be thought of as:

- the ratio of the wave speed to mean speed of the flow

- the ratio of potential energy to kinetic energy (or the ratio of buoyancy to inertial forces)

- a description of the minimum energy state of the flow

Flow regime and Froude number effects

The Froude number dictates the ‘flow regime’. Principally, there are three regimes of flow: supercritical ($Fr > 1$), subcritical ($Fr < 1$) and critical ($Fr = 1$).

Ramifications? Hydraulic control – location within flow that regulates flow rate.

Supercritical flow – Hydraulically controlled from upstream.

Subcritical flow – Downstream control.

Critical flows do not exist naturally (they are unstable). If a flow passes through $Fr = 1$, a **hydraulic jump** will occur.