

FLUID MECHANICS & HYDRAULICS

Uniform Flow Dynamics

Hydraulic approaches, velocity profiles, and acoustic measurement techniques.

Hydraulic Force Balance

- **Pressure Equilibrium:** Constant water depth cancels forces.

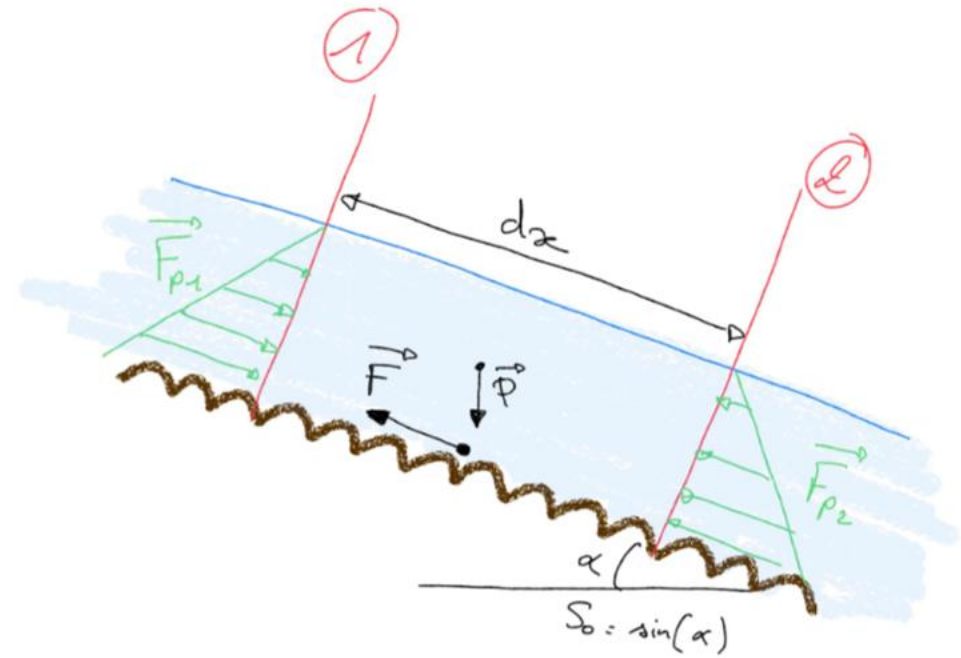
$$\vec{F}_{p1} = -\vec{F}_{p2}$$

- **Gravity Projection:** Weight drives downslope movement.

$$P_x = \rho (A_m dx) g S_0$$

- **Bed Friction:** Bottom shear stress resists flow.

$$F_x = -\tau_b (P_m dx)$$



SHEAR STRESS EQUILIBRIUM

$$\tau_b = \rho g R_h S_0$$

SLIP VELOCITY

$$u_* = \sqrt{\tau_b / \rho}$$

Empirical Friction Laws

Estimating mean velocity in turbulent uniform flow with empirical formula

Chézy

$$U = \textcolor{red}{C} \sqrt{R_h S_0}$$

Root-proportionate shear correlation.

Darcy-Weisbach

$$U = \sqrt{\frac{8g}{\textcolor{red}{f}}} \sqrt{R_h S_0}$$

Standardized pipe-flow friction factor.

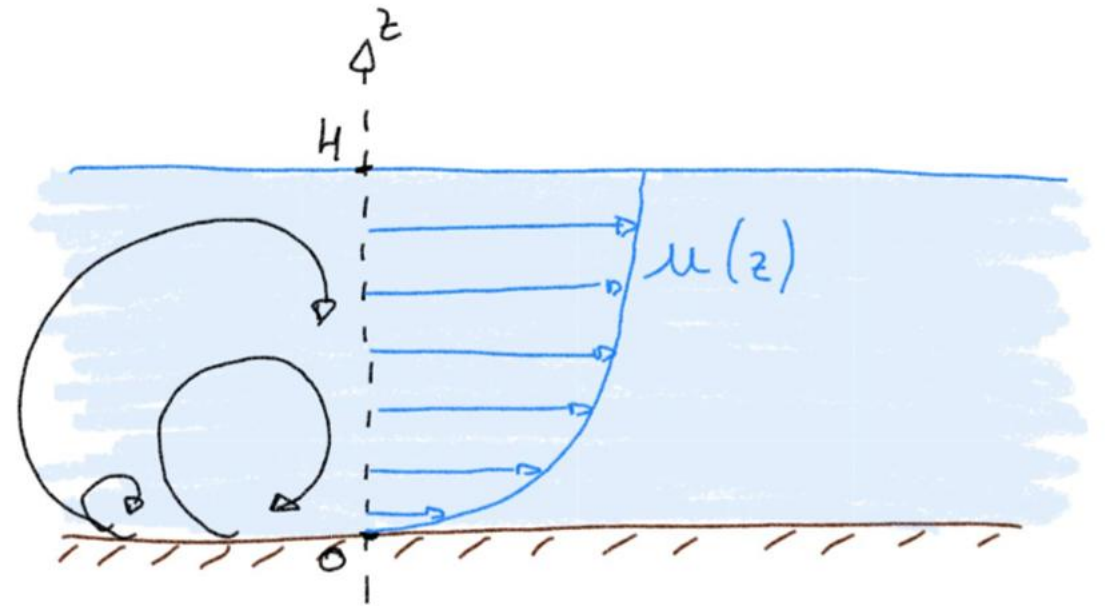
Manning-Strickler

$$U = \frac{1}{\textcolor{red}{n}} \frac{R_h^{2/3} S_0^{1/2}}{2}$$

Empirical surface roughness coefficient.

$\textcolor{red}{C}$ and $\textcolor{red}{f}$ are dynamically calculated, $\textcolor{red}{n} \approx 0.012 - 0.05$

Velocity Profile Determinants



01

Boundary Layer

Vertical fluid shear development.

02

Turbulent Dynamics

Fluctuating momentum transfer eddies.

03

Bottom Friction

Bed shear stress constraint.

FLUID MECHANICS APPROACH

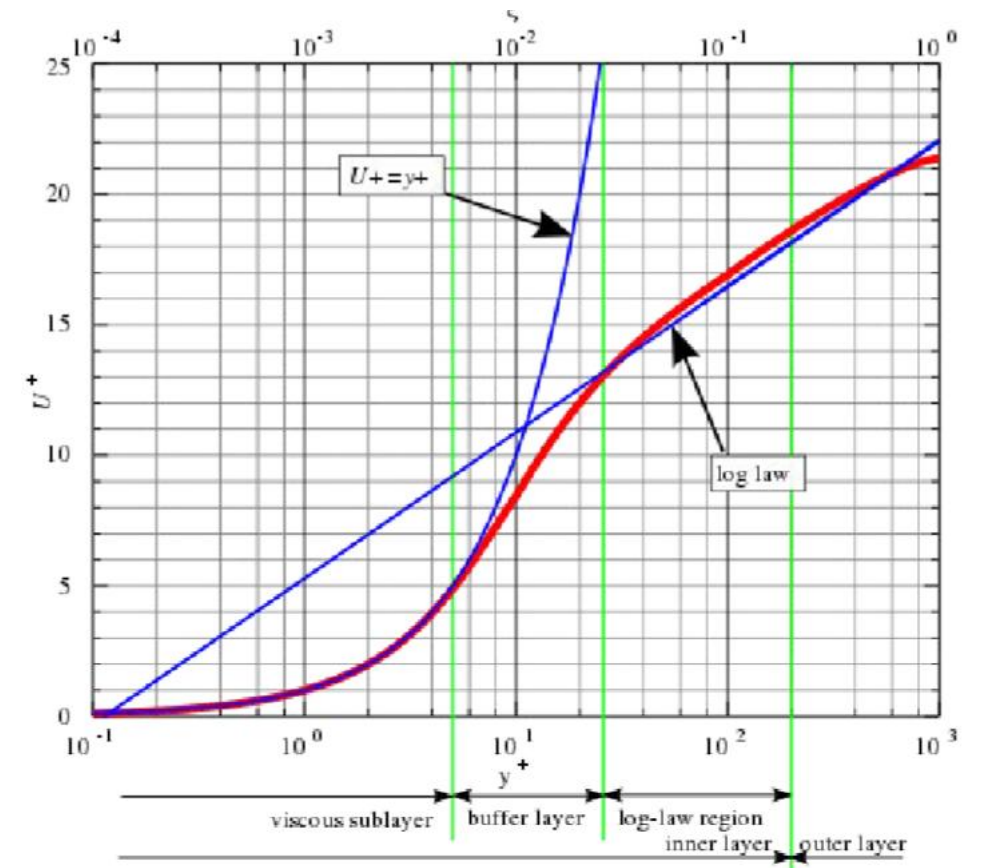
Law of the Wall Smooth Bed

Viscous Sublayer

Linear dimensionless velocity mapping.

Log-Law Region

Logarithmic distribution via Von-Karman.



VISCOUS REGION ($z^+ < 5$)

LOG REGION ($z^+ > 40$)

$$u^+ = z^+$$

$$u^+ = 1/\kappa \ln(z^+) + A$$

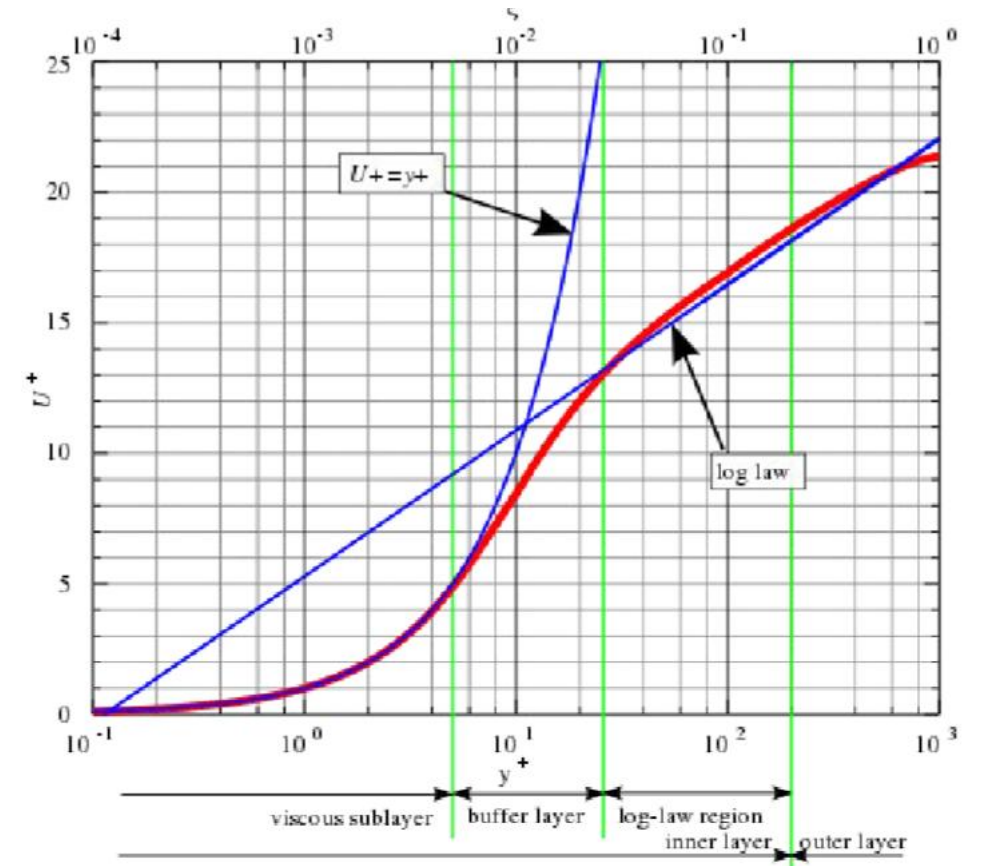
$$\kappa = 0.41 \text{ and } A = 5.5$$

Law of the Wall / Rough Bed

Nikuradse Scale Equivalent sand roughness dimension.

Sublayer Destruction Viscous sublayer ceases existing.

Shifted Profile Roughness-dependent logarithmic velocity shift.



ROUGHNESS THRESHOLD

$$K_s^+ = \frac{k_s u_*}{\nu} > 70$$

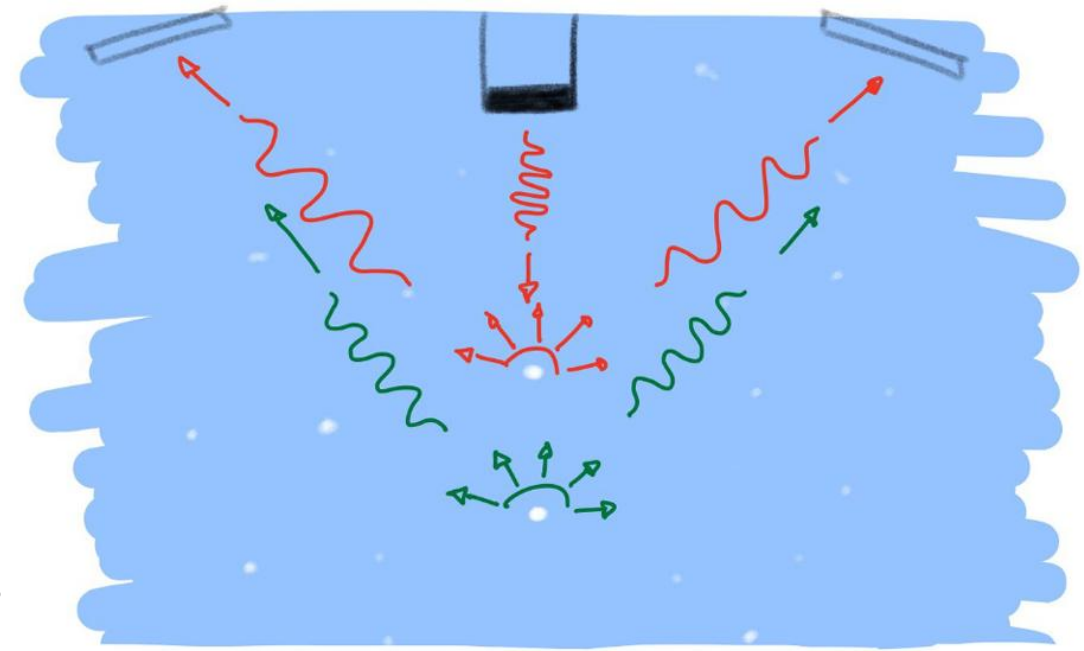
ROUGH BED VELOCITY FORMULA

$$\frac{u}{u_*} = 1/\kappa \ln(z/k_s) + B$$

Empirical coefficient $B = 8.5$

Acoustic Velocity Profiling

- 01 Emission** 1MHz ultrasound carrier wave.
- 02 Backscattering** Micro-tracer wave reflection.
- 03 Doppler Shift** Frequency-derived tracer velocity.



U

V

W

