Sediment Transport Dynamics, Part I

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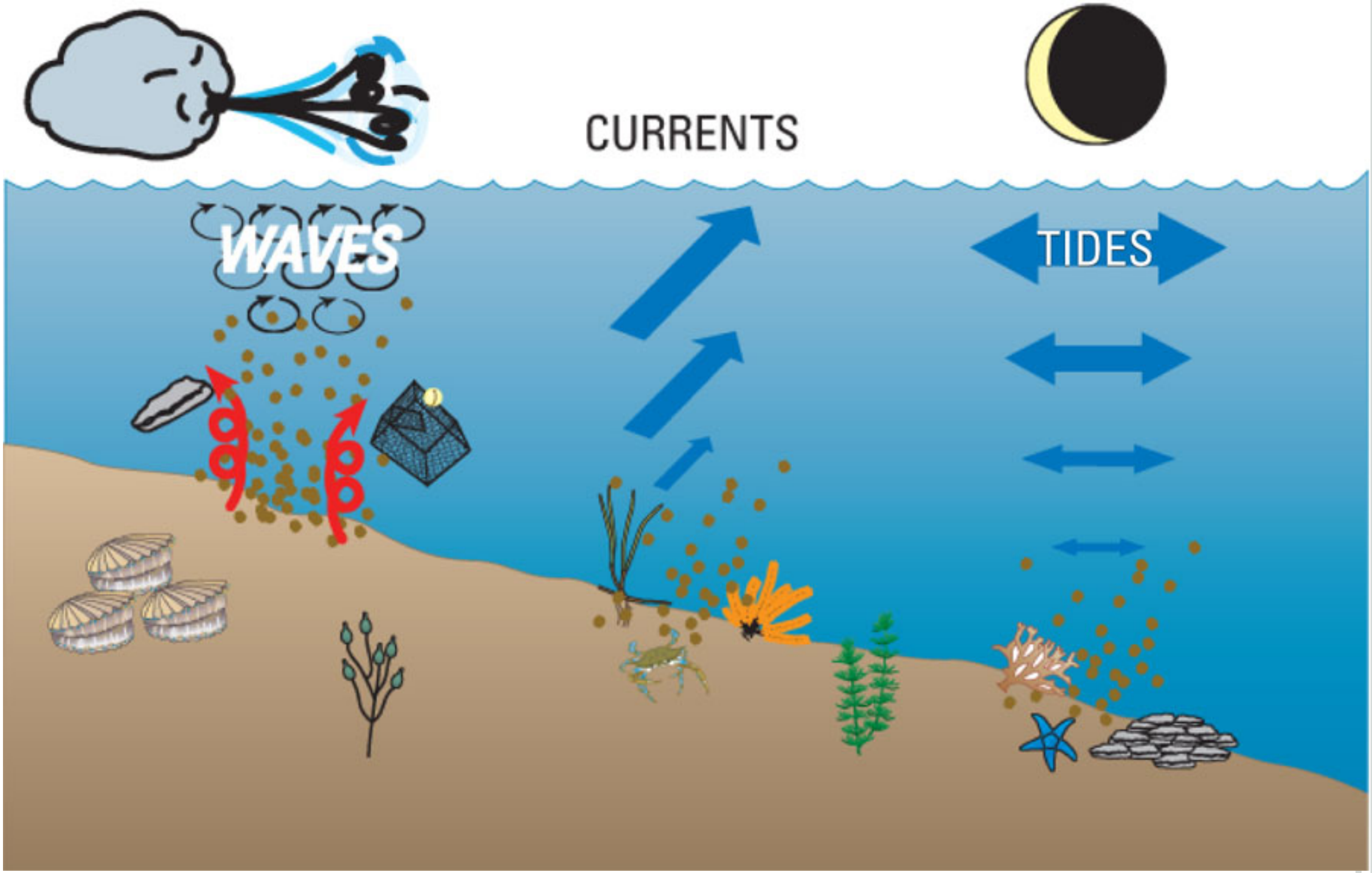
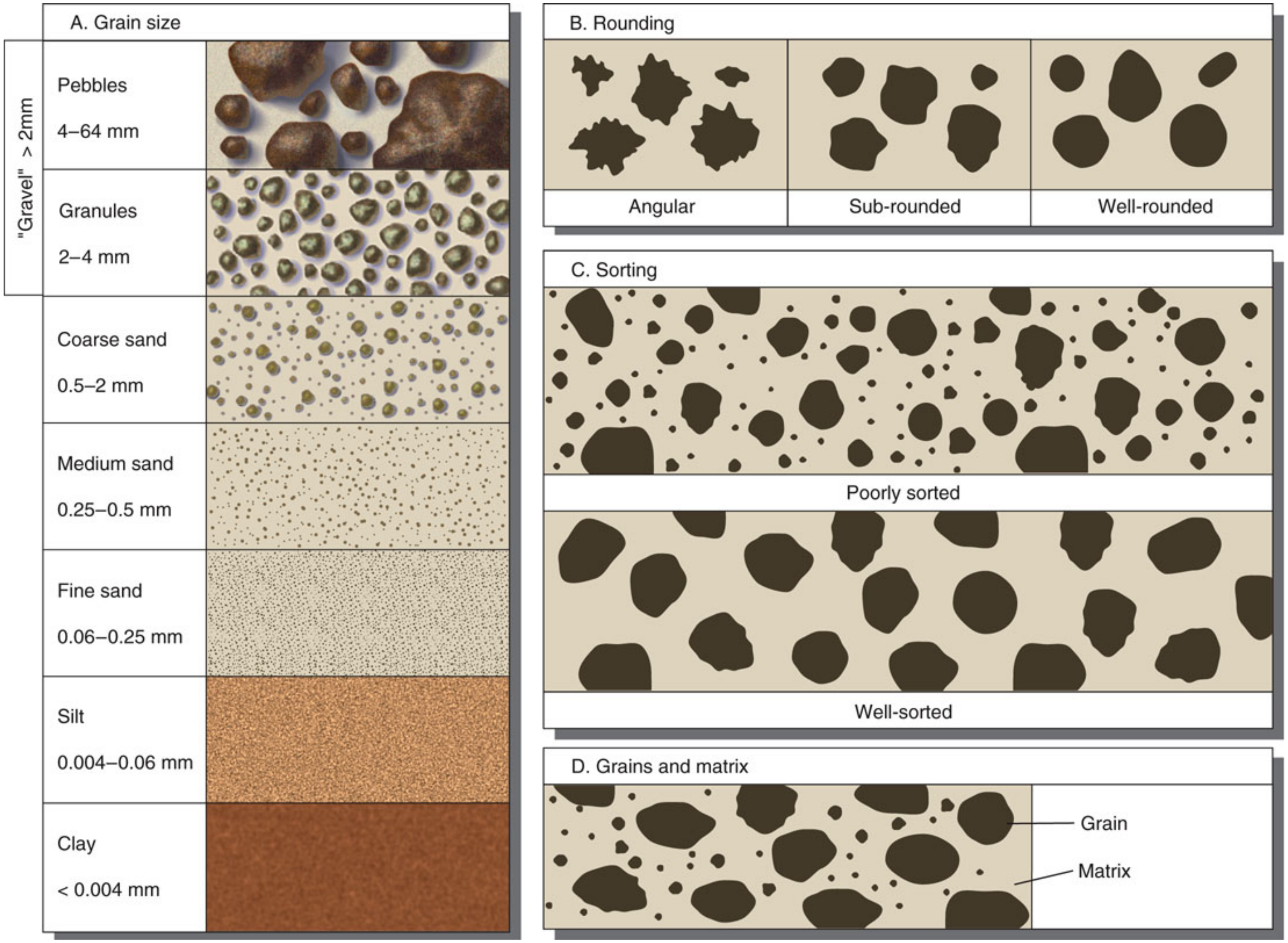
Sediment Characteristics
- Grain Size, Distribution, Bottom Roughness
- Density, Fall Velocity

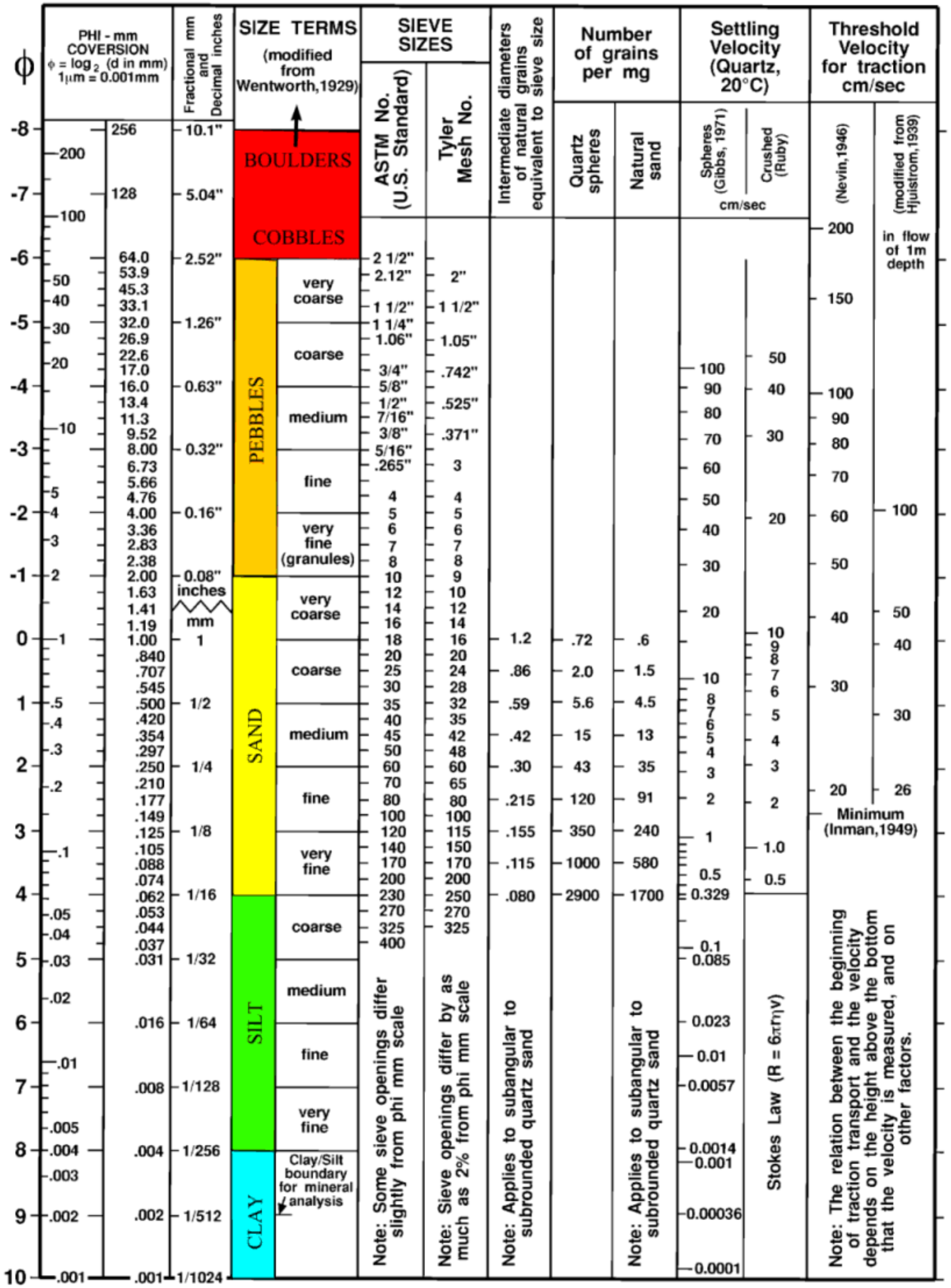
Factors influencing non-cohesive sediment transport
- Initiation of Motion, Turbulence, Bottom Stress
- Conservation of Momentum -> Sediment Velocity
- Conservation of Mass -> Sediment Concentration



USGS –Forcing Mechanisms for
Sediment Transport on Continental Shelves

Sediment Grain Size





$$\phi = -\log_2 D/D_0,$$

where

ϕ is the Krumbein phi scale,

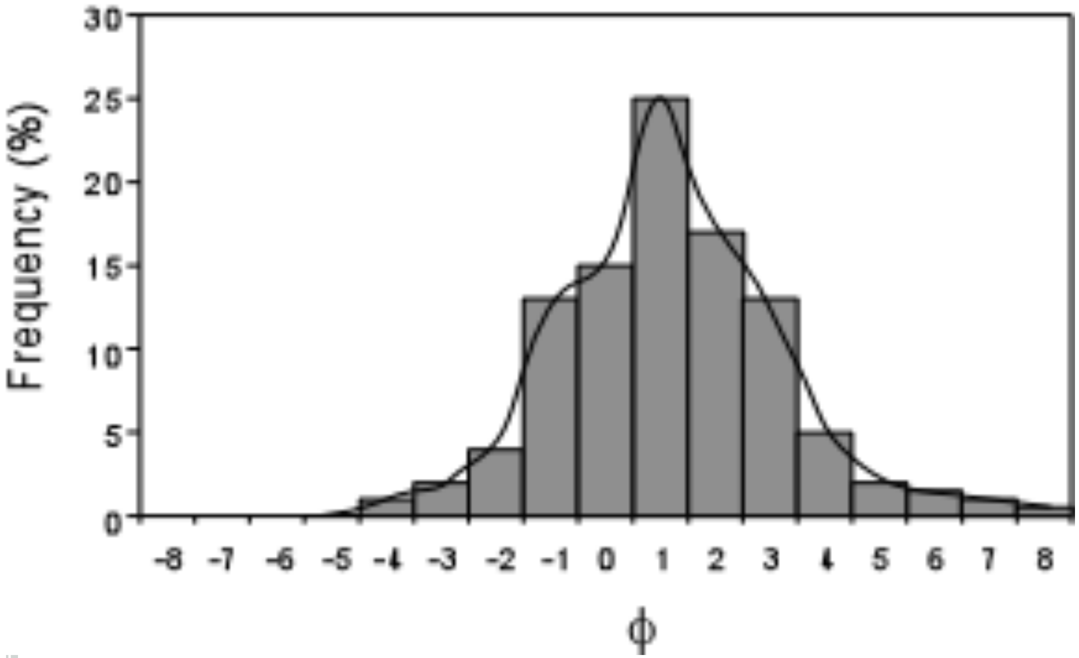
D is the diameter of the particle, and

D_0 is a reference diameter, equal to 1 mm (to make the eq

This equation can be rearranged to find diameter using ϕ:

$$D = D_0 \times 2^{-\phi}$$

Sediment Grain Size



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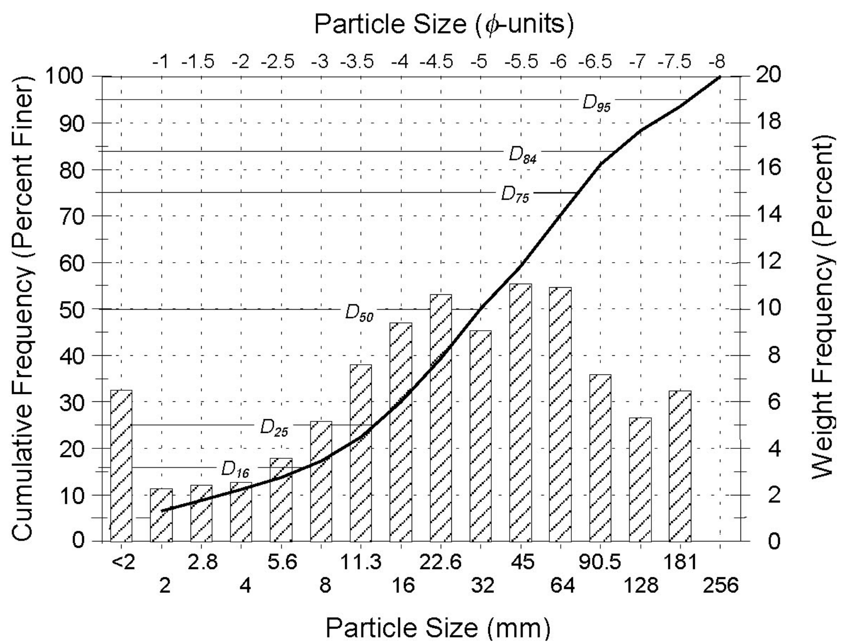


Fig. 2.12: Frequency distribution (histogram with hatched bars) and cumulative frequency distribution curve (thick line) with indicated percentile values for data listed in Table 2.3.

Sediment Grain Size

Sediment Density

TABLE 6.5 Formula and Specific Gravity of Common Soil Minerals

Type of mineral	Formula	Specific gravity	Comments
Quartz	SiO_2	2.65	Silicate, most common type of soil mineral
K Feldspar	$KAlSi_3O_8$	2.54–2.57	Feldspars are also silicates and are the second most common type of soil mineral.
Na or Ca Feldspar	$NaAlSi_3O_8$	2.62–2.76	
Calcite	$CaCO_3$	2.71	Basic constituent of carbonate rocks
Dolomite	$CaMg(CO_3)_2$	2.85	Basic constituent of carbonate rocks
Muscovite	varies	2.76–3.0	Silicate sheet type mineral (mica group)
Biotite	complex	2.8–3.2	Silicate sheet type mineral (mica group)
Hematite	Fe_2O_3	5.2–5.3	Frequent cause of reddish-brown color in soil
Gypsum	$CaSO_4{\cdot}2H_2O$	2.35	Can lead to sulfate attack of concrete
Serpentine	$Mg_3Si_2O_5(OH)_4$	2.5–2.6	Silicate sheet or fibrous type mineral
Kaolinite	$Al_2Si_2O_5(OH)_4$	2.61–2.66	Silicate clay mineral, low activity
Illite	complex	2.60–2.86	Silicate clay mineral, intermediate activity
Montmorillonite	complex	2.74–2.78	Silicate clay mineral, highest activity

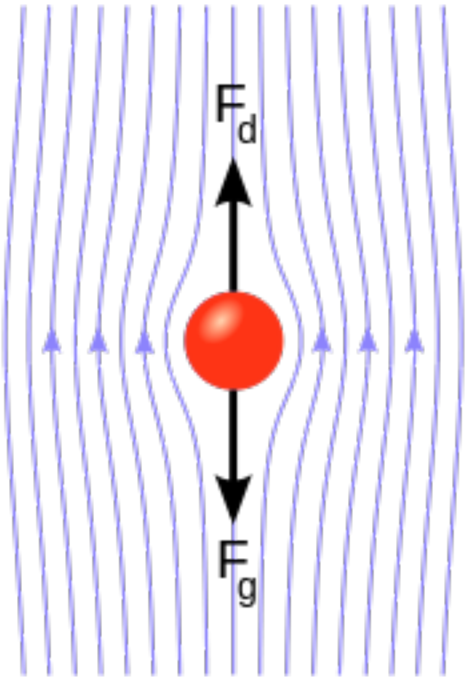
NOTE: Silicates are very common and account for about 80% of the minerals at the Earth's surface.

$$S.G. = \frac{Density of\ object}{Density of\ Water} = \frac{174.8 \frac{lbs}{ft^3}}{62.4 \frac{lbs}{ft^3}} = 2.8$$

Water Viscosity

Temperature - t - (^oC)	Dynamic Viscosity - μ - (Pa s, N s/m^2) x 10^{-3}	Kinematic Viscosity - ν - (m^2/s) x 10^{-6}
0	1.787	1.787
5	1.519	1.519
10	1.307	1.307
20	1.002	1.004
30	0.798	0.801
40	0.653	0.658
50	0.547	0.553
60	0.467	0.475
70	0.404	0.413
80	0.355	0.365
90	0.315	0.326
100	0.282	0.29

Sediment Fall Velocity



BUOYANT FORCE

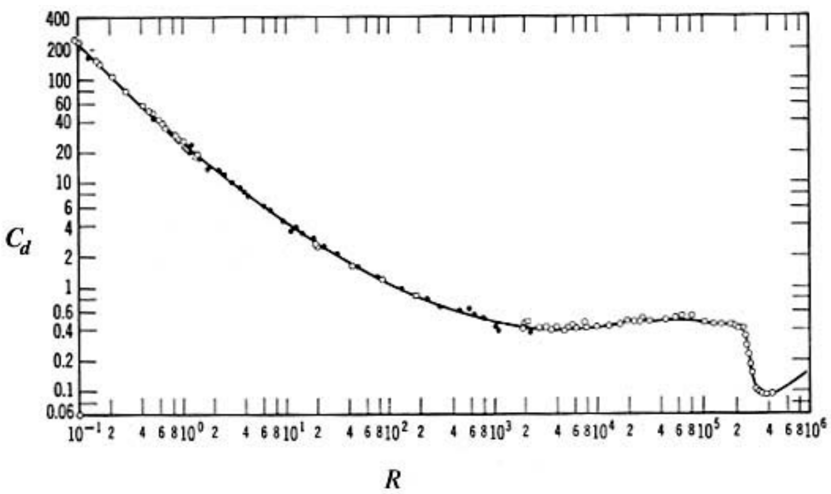
$$F_G = (\rho_P - \rho)\, g\, V_P$$

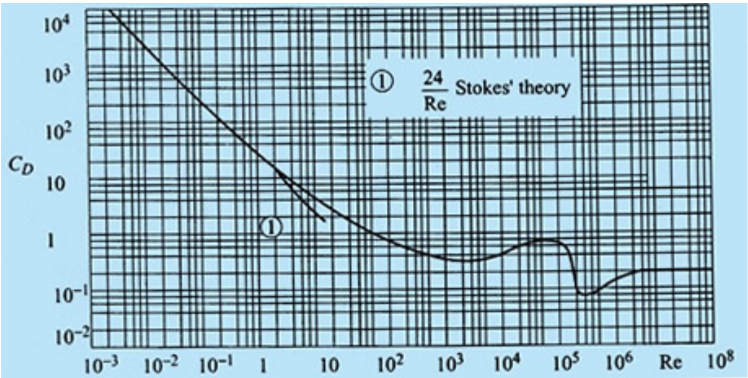
- ρ_P — density of particle
- ρ — density of fluid
- g — gravitational constant
- V_P — volume of particle

DRAG FORCE

$$F_D = \frac{C_D A_P \rho v_S^2}{2}$$

- C_D — drag coefficient
- A_P — area of particle
- ρ — fluid
- v_S — settling velocity





Sediment Fall Velocity

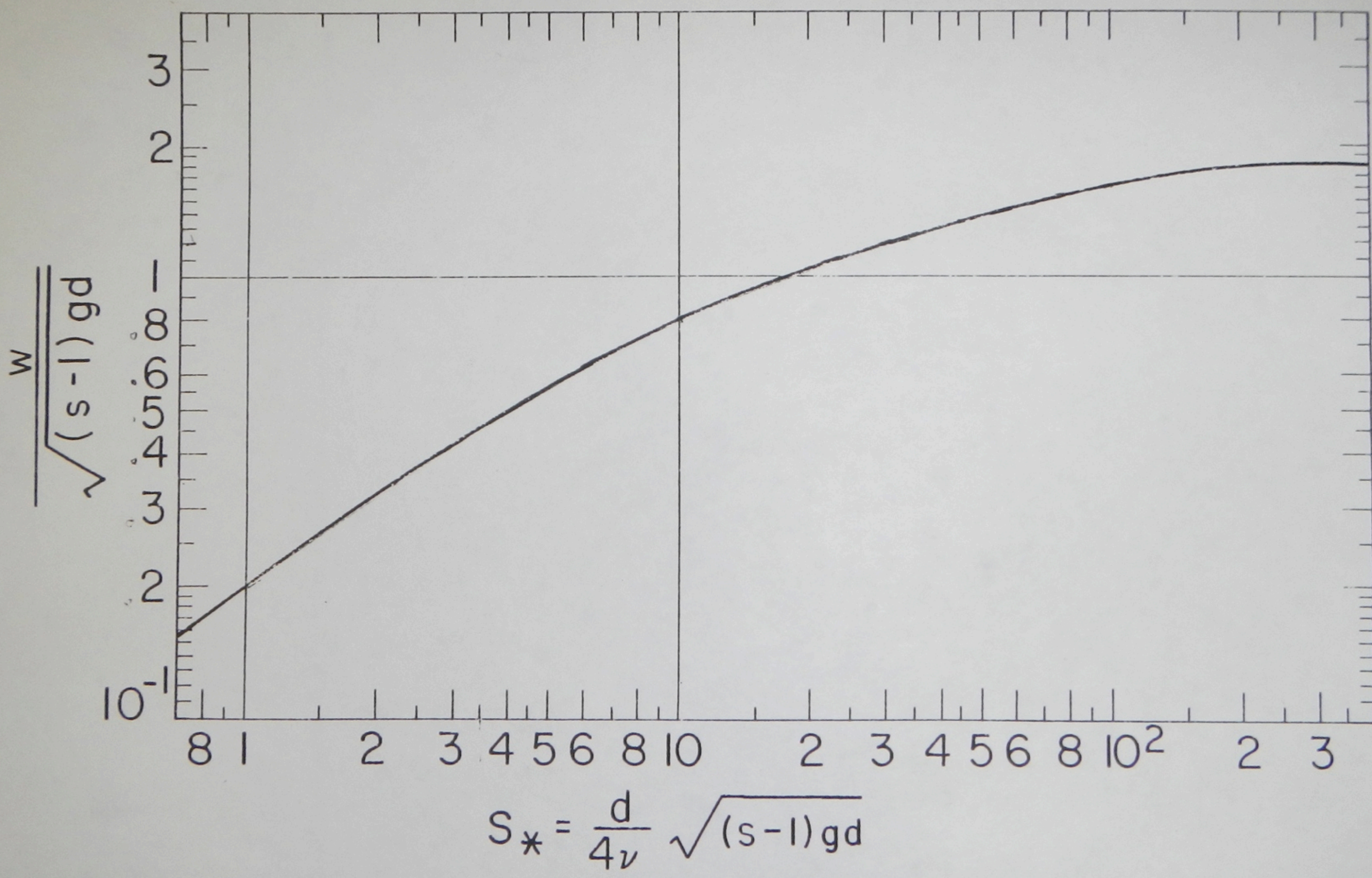


Figure 3 : Determination of the Fall Velocity of a Spherical Particle.

Bottom Stress

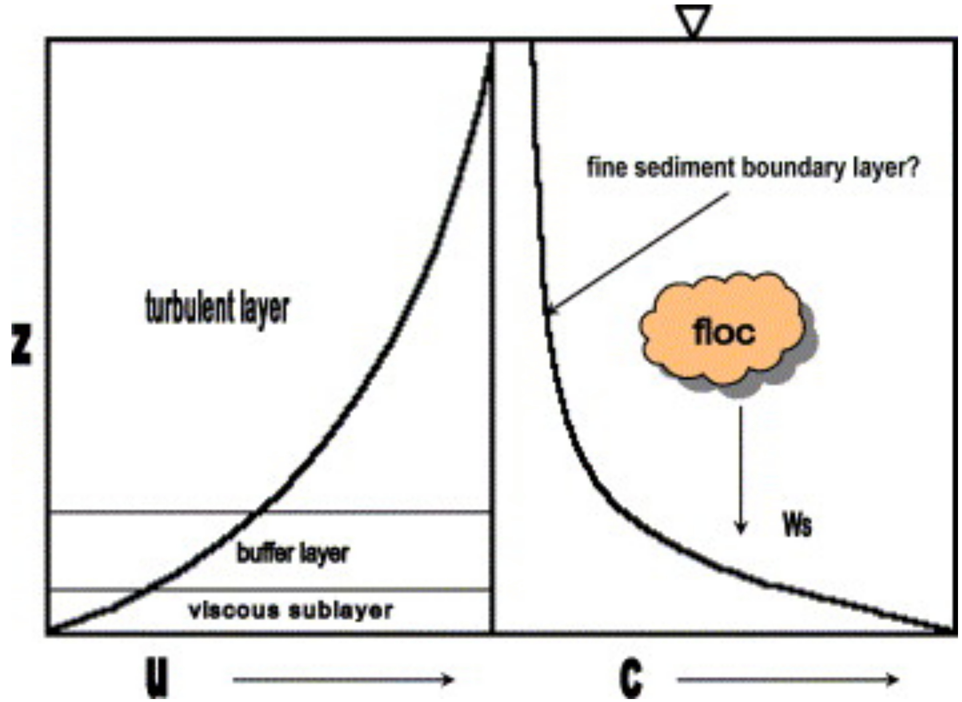


Figure 2 The structures of turbulent boundary layer and fine sediment boundary layer. Z <ce:hsp sp="0.25"/> =<ce:hsp sp="0.25"/> the height above the bed; u <ce:hsp sp="0.25"/> =<ce:hsp sp="0.25"/> the current velocity; C <ce:hsp sp="0.25"/> =<ce:hsp sp...

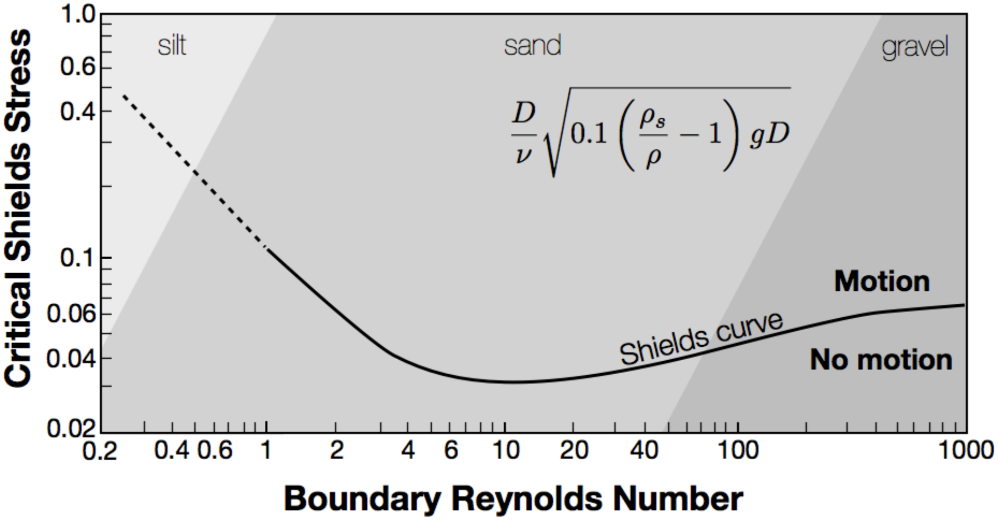
John Z. Shi , S.Y. Zhang , L.J. Hamilton

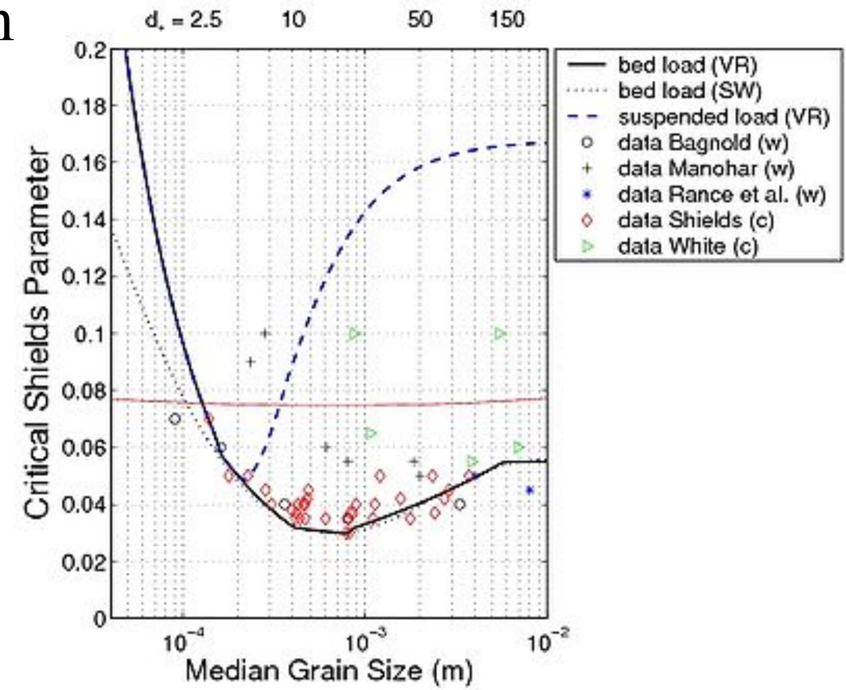
Bottom fine sediment boundary layer and transport processes at the mouth of the Changjiang Estuary, China

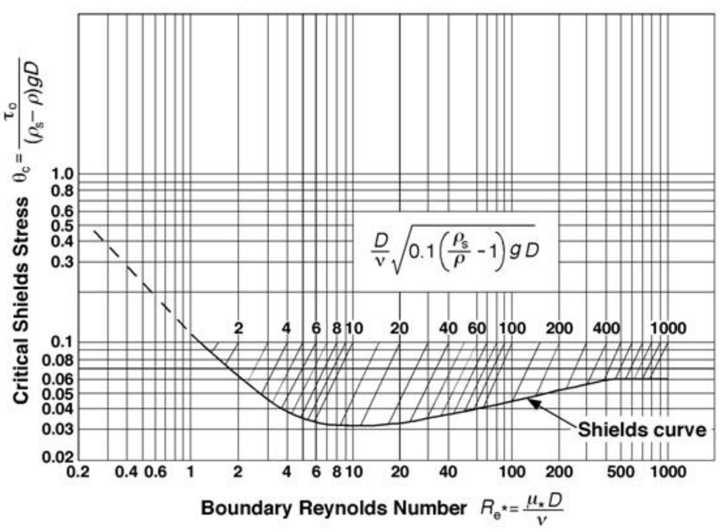
Journal of Hydrology Volume 327, Issues 1–2 2006 276 - 288

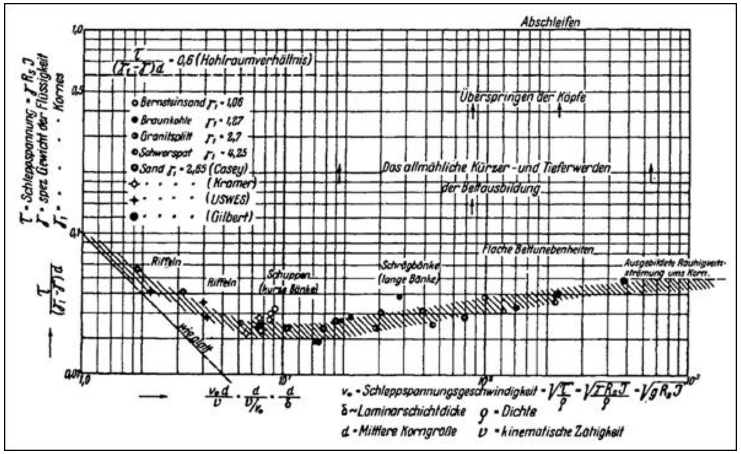
http://dx.doi.org/10.1016/j.jhydrol.2005.11.039

Shields Criteria – Initiation of Motion









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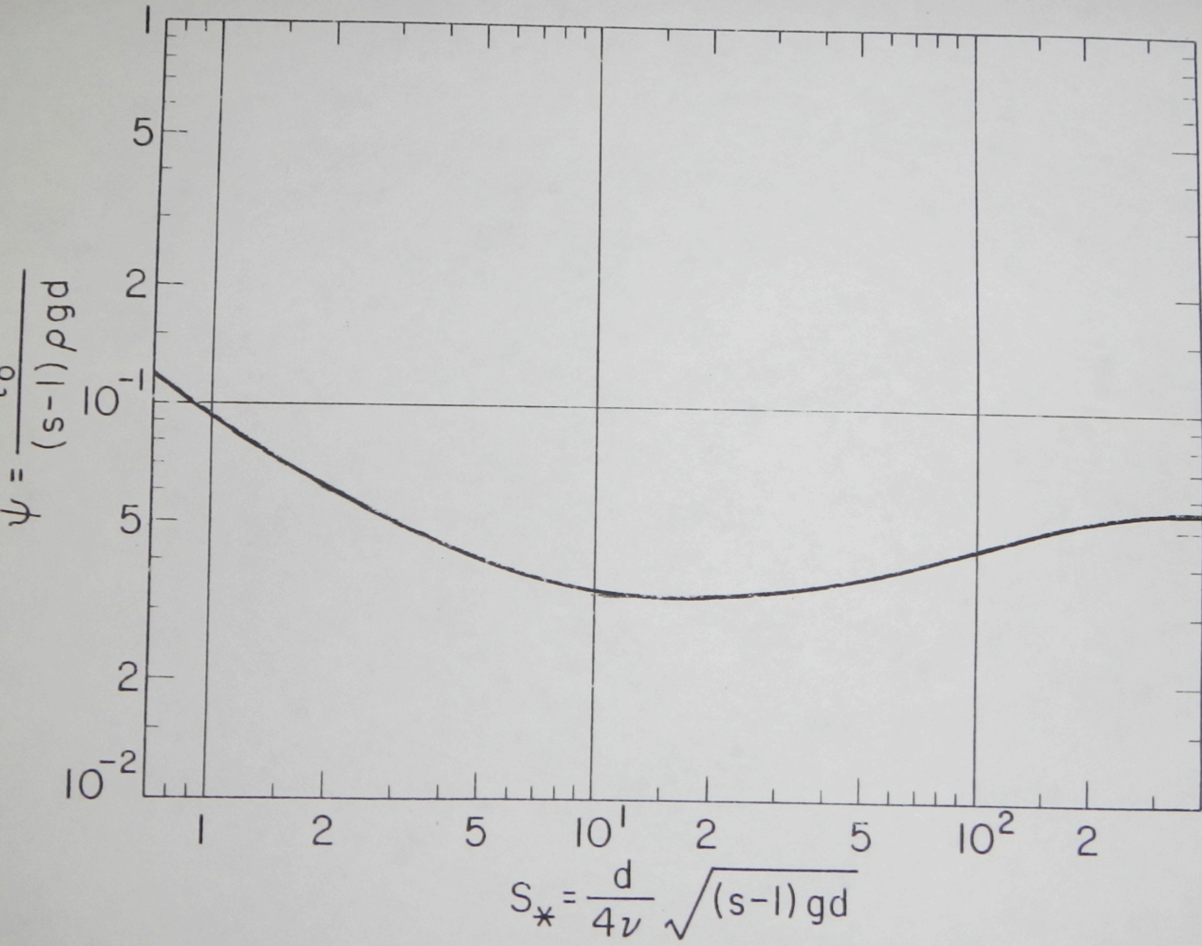
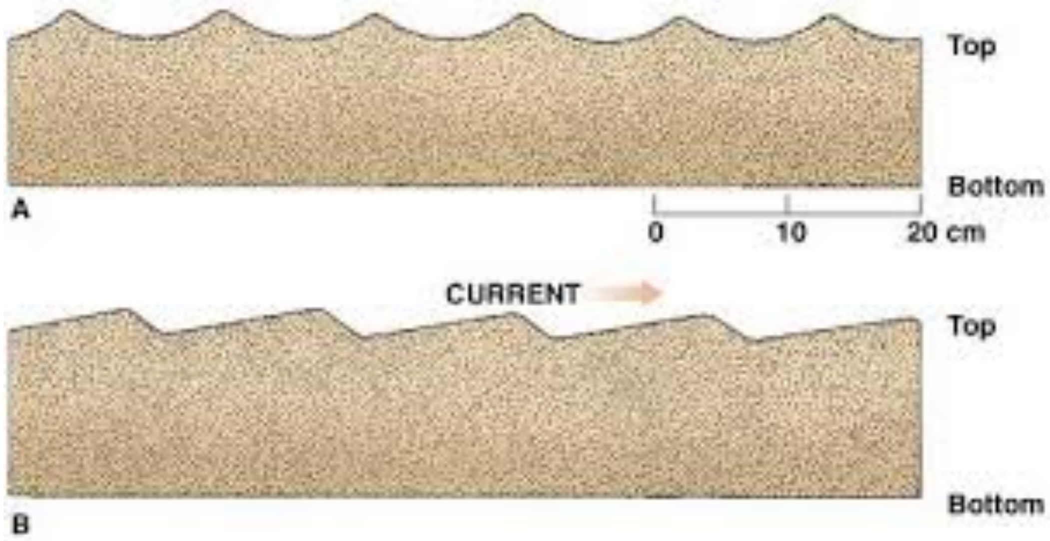


Figure 5: Modified Shields Diagram

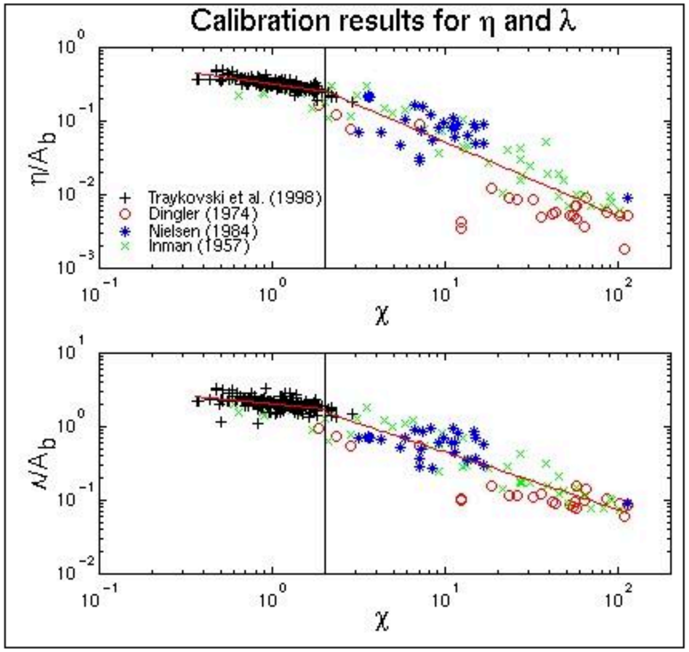
Bottom Roughness



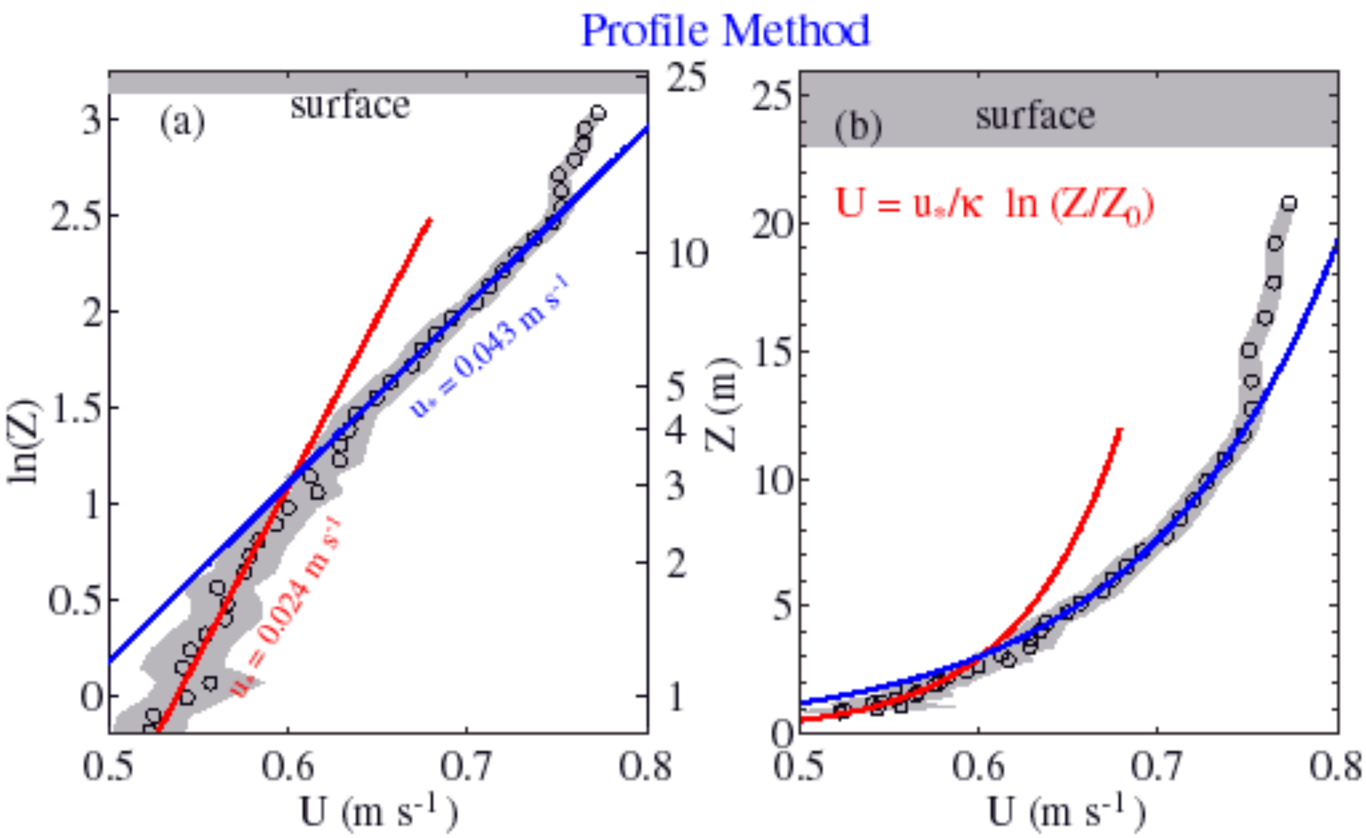
$$\frac{\eta}{A_b} = \begin{cases} 0.32X^{-0.34} & X < 2 \\ 0.52X^{-1.01} & X > 2 \end{cases}$$

$$\frac{\lambda}{A_b} = \begin{cases} 2.04X^{-0.23} & X < 2 \\ 2.70X^{-0.78} & X > 2 \end{cases}$$

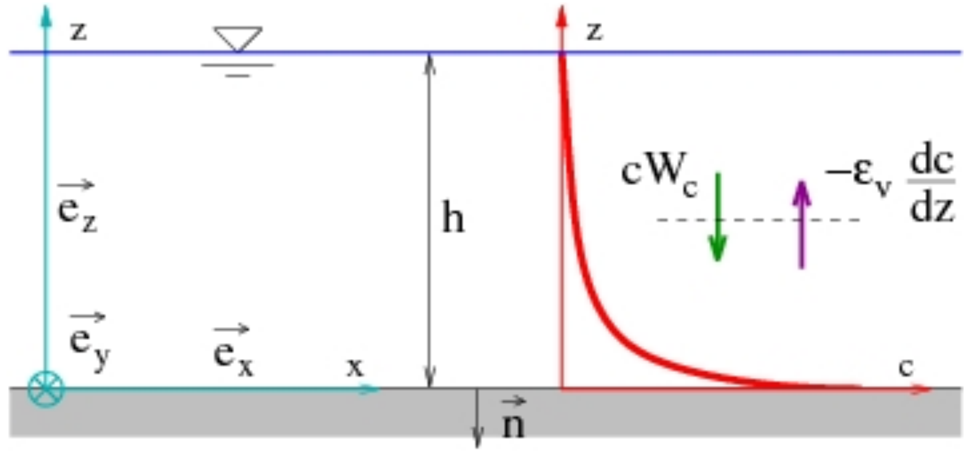
$$X = \frac{4\nu u_b^2}{d[(s-1)gd]^{3/2}}$$

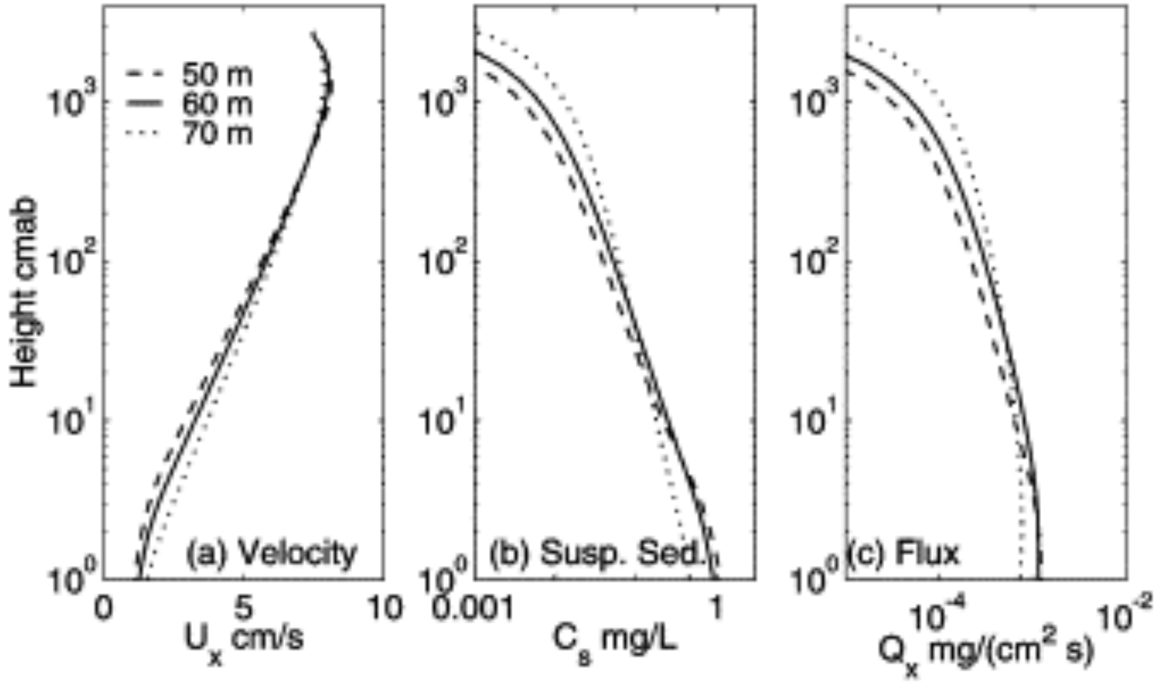


Constant Stress Layer - Currents



Constant Stress Layer – Suspended Sediment





Sediment Transport Dynamics, Part II

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Factors influencing cohesive sediment transport

Flocculation/hindered settling
Fluid mud/Sediment gravity flows

Applications to the Amazon system

Fluid Muds on the Amazon Shelf
Downslope flux to clinoform foreset
Nearshore Processing – e.g., sediment deposition /progradation processes on mud capes