Name	Date	Grade

Lab Exercise #2-Positive and Negatives of Soil Sediments (???)

Factors that Influence Sediment Transport

Lab Objective (3-5 bullets):

1. UNDERSTAND DIFFERENT types of water erosion
2.

Lab Introduction Narrative (3-5 sentences):

Text References:

Sediment Transport and Deposition

http://www.fondriest.com/environmental-measurements/parameters/hydrology/sediment-transport-deposition/

Tools and Materials:

Safety Precautions:

Procedures:

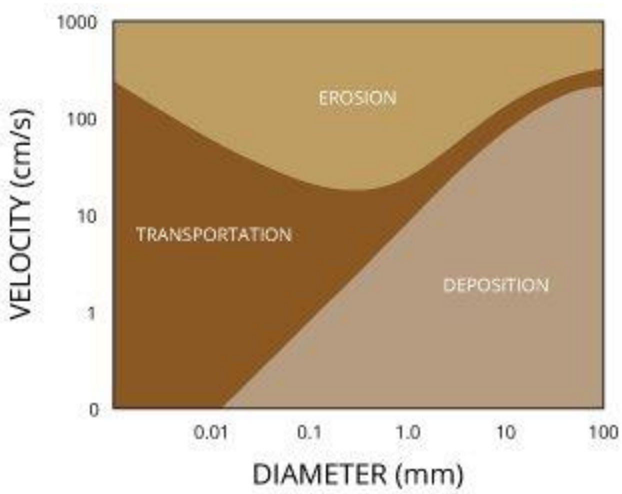
Work through the Water Flow equations and compare the effect of different values for selected parameters:

Maintenance of Workstation and Tools:

Summary Statement:

Lab-covered Questions (15-points):

Water Flow

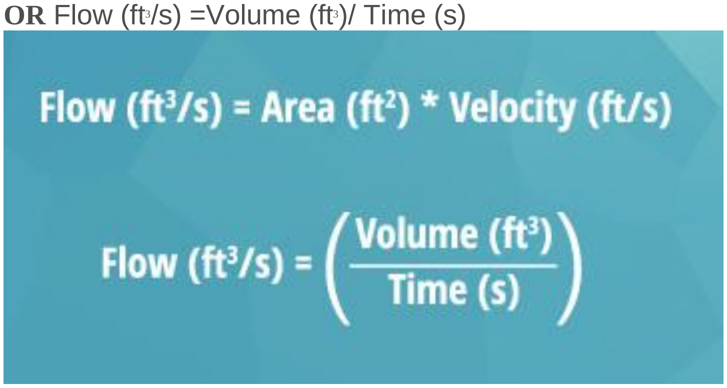


Whether sediment will be eroded, transported or deposited is depended on the particle size and the flow rate of the water.

Water flow, also called water discharge, is the single most important element of sediment transport. The flow of water is responsible for picking up, moving and depositing sediment in a waterway [26]. Without flow, sediment might remain suspended or settle out – but it will not move downstream. Flow is required to initiate the transport [18]. There are two basic ways to calculate flow. Water discharge can be simplified as area (a cross-section of the waterway) multiplied by velocity, or as a volume of water moved over time [25].

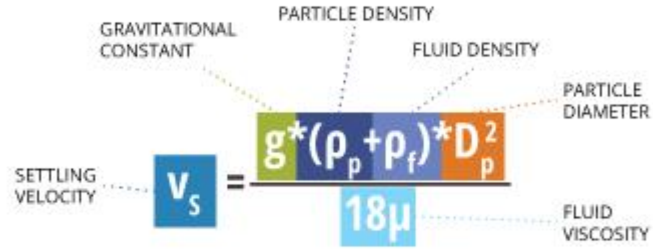
Flow (ft^3/s) =Area (ft^2) * Velocity (ft/s)

OR Flow (ft^3/s) =Volume (ft^3)/ Time (s)



The equations describing the relationship of water flow and sediment transport are a bit more complex. The complexity of sediment transport rates are due to a large number of unknowns (e.g. bed geometry, particle size, shape and concentration), as well as multiple forces acting upon the sediment (e.g. relative inertia, turbulent eddies, velocity fluctuations in speed and direction) [11]. The sediment transport rate in particular is difficult to measure, as any measurement method will disturb the flow and thus alter the reading. Most flow rate and sediment transport rate equations attempt to simplify the scenario by ignoring the effects of channel width, shape and curvature of a channel, sediment cohesion and non-uniform flows [11].

The two main flow factors in sediment transport are the settling rate and the boundary layer shear stress[27]. The settling rate (also called Stokes settling) is the rate at which sediment falls through a liquid and it is controlled by the drag force (keeping a particle suspended) and the gravitational force (a function of the particle size) [27]. Understanding this relationship helps to define some of the forces that sediment transport has to overcome relative to particle size.



$v_s = (g * (\rho_p - \rho_f) * D_p^2) / 18\mu$

v_s = settling velocity

g = gravitational constant

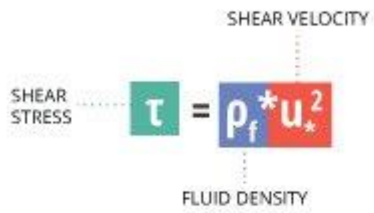
ρ_p = particle density

ρ_f = fluid density

D_p = particle diameter

μ= fluid viscosity [29]

Shear stresses in the boundary layer of a sediment bed explain how much force is required for water flow to overcome relative inertia and begin sediment transport (through bedload or suspended load) [27].



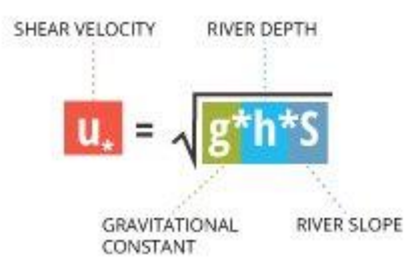
$\tau = \rho_f * u_*^2$

τ = shear stress

ρ_f = fluid density

u_* = characteristic velocity of turbulent flow (shear velocity) (see following equations) [27]

In a basic freshwater river system, u_* can be calculated as:



$u_* = Sqrt(g * h * S)$

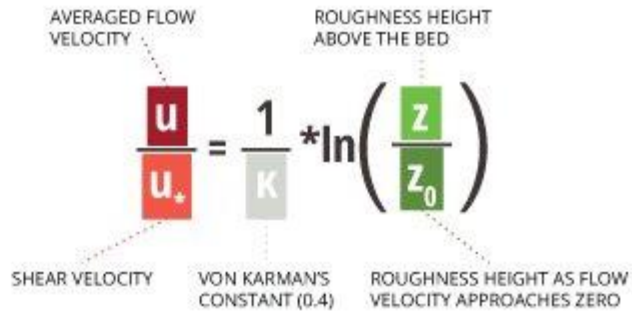
u_* = shear velocity

g = gravitational constant

h = river depth

S = river slope [27]

In the ocean and in other more complex water systems, this equation is inadequate. Instead, the Von Karman-Prandlt equation should be used. The shear stress is influenced not only by the viscosity of the liquid, but the roughness of the sediment [27]. The turbulent eddies created at the bottom by water flow must also be accounted for. This is also known as the Law of the Wall [30].



$u/u_* = (1/\kappa) * \ln(z/z_0)$

u = averaged flow velocity

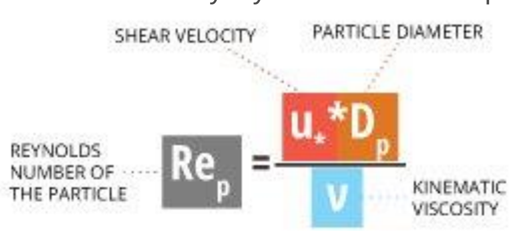
u_* =shear velocity

κ = Von Karman's constant (0.4)

z = roughness height above the bed

z_0 = roughness height as flow velocity approaches zero [30]

The above equations help to give a basic understanding of some of the forces acting on sediment in the water. To further understand the conditions required for sediment transport, the Shields stress equation can be used. Shields stress, along with the particle Reynolds number, can be used to predict how much flow is required for substantial sediment transport [27]. The Reynolds number is an expression of a particle's resistance to viscous force [28]. In other words, the Reynolds number demonstrates whether or not a flow is viscous enough to overcome the relative inertia of sediment. For sediment transport, the Reynolds number for flow through a sediment bed can be calculated from the boundary layer shear stress equation:



$Re_p = (u_* * D_p) / \nu$

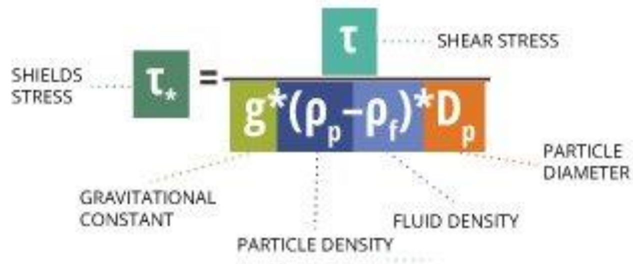
Re_p = Reynolds number of the particle

u_* = characteristic velocity of turbulent flow (shear velocity)

D_p = particle diameter

v = kinematic viscosity (viscosity/ fluid density, (μ/ρ_f))[27]

The point at which water flow begins to transport sediment is called the critical Shields stress [27]. This creates an empirical curve to approximate at what flow rate a sediment particle will move (based on particle size) [27].



$\tau_* = \tau /(g * (\rho_p - \rho_f) * D_p)$

τ_* = Shields stress

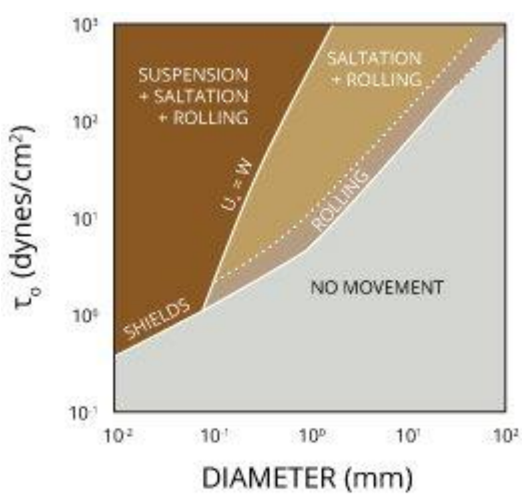
τ = shear stress

g = gravitational constant

ρ_p = particle density

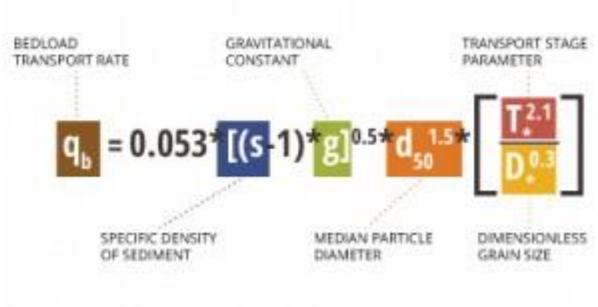
ρ_f = density of fluid

D_p = particle diameter [13]



The critical Shields stress is the defining boundary between inertia and transport; when the flow rate is capable of moving particles of a specific size.

While these equations help define minimum flow rates for sediment transportation, they do not determine sediment load and sediment transport rates themselves. One sediment transport rate equation was developed by van Rijn, for the bedload transport of particles between 0.2-2mm.



$q_b = 0.053 * [(s-1)*g]^{0.5} * d_{50}^{1.5} * [T_*^{2.1} / D_*^{0.3}]$

q_b = bedload transport rate

s= specific density of sediment

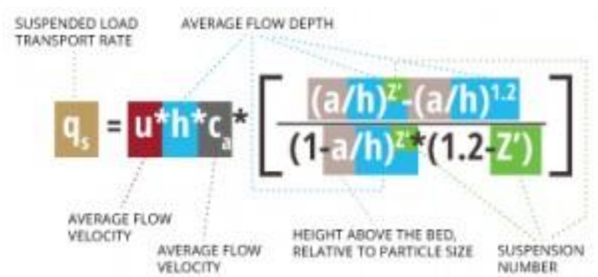
g = gravitational constant

d_{50} = median particle diameter

T_* = transport stage parameter

D_* = dimensionless grain size [18]

The suspended load transport rate (still assuming cohesionless sediment and a sediment size of 0.2-2mm) is even more complicated:



$q_s = u * h * c_a * [((a/h)^{Z'} – (a/h)^{1.2}) / ((1-a/h)^{Z'} * (1.2-Z'))]$

q_s= suspended load transport rate

u = average flow velocity

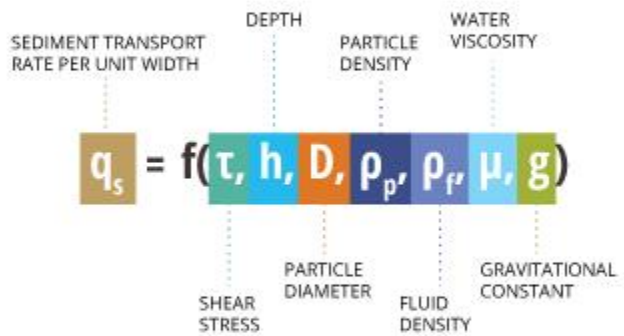
h = average flow depth

c_a= reference concentration

a = height above the bed, relative to particle size

Z' = suspension number [18]

Other sediment rating curves have been developed, but they cannot be equally applied to all water bodies [13]. This is because in any application, there are seven main variables that have an effect on sediment transport rates [11,31].



$q_s = f(\tau, h, D, \rho_p, \rho_f, \mu, g)$

q_s = sediment transport rate per unit width

τ = shear stress

h = depth

D = particle diameter

ρ_p = particle density

ρ_f = fluid density

μ = water viscosity

g = gravitational constant

The sediment transport rate is a function of these seven variables, as well as the size-shape-density distribution (often assumed as a standard deviation of the particle diameter) of the suspended particles[31]. In addition, the largest river discharge does not automatically mean that a river will have the largest sediment load. The quantity and material of the sediment particles, as well as the geography of the local terrain will still play a contributing role in the sediment load [10].

The sediment load itself is calculated as a depth-integrated sediment mass above a unit area [11]. It is variable for multiple reasons, but can be estimated with a time-average collected sediment concentration[11]. While it is dependent on flow to initiate and continue transport, it is not calculated from flow rates, as the main variables in sediment load come from environment factors.

Lab Participation (10-points):

Element	Excellent	Proficient	Partially Proficient	Below Proficient	Unsatisfactory	Points
Student Lab Participation	5 points The student is engaging thoroughly, with well thought out questions and answers.	4 points For the student to answer (or ask a question) to engage in the discussion, he/she is engaging, but sometimes is not fully explained or developed.	3 points The student's question/answer was somewhat proficient but could have been expanded upon	2 points- 1 pt. The student's answers was minimal and did not address much of the issues or topics in order to be engaging.	0 points Engagement was neither attempted nor completed	__/5
Student Lab Performance	5 points The student's actions, feedback and comments were thought-provoking and had substance	4 points The student's actions, feedback, and comments were good but could be expanded upon	3 points The student's actions, feedback, and comments made were minimal and did not provide much depth	2 points- 1 pt. The student's actions, feedback, and comments were one sentence that did not expand upon the lab topic	0 points No responses or feedback were given by student	__/5
Total points						__/ 10