SEDIMENT DYNAMICS IN THE BENTHIC BOUNDARY LAYER

A LABORATORY AND HOMEWORK ACTIVITY

PURPOSE

This activity guides students through quantitative analysis of real nearshore sedimentation data. Students should have previously learned the theory behind critical shear stress as it applies to sediment transport in the benthic boundary layer. In this activity, the students will apply these theories to predict sediment transport along a continual shelf. Students will ultimately create a connection between these seemingly abstract theories and the stability of coastal communities.

Activity:

Sedimentological studies were carried out on the Washington continental shelf.
Surface sediment from cores were analyzed for grain size (Table 1).

Table 1. Washington shelf, experimental transect

Station Number:	5	23	24
Station Depth:	19 m	53 m	73 m
Size (mm)	Wt %	Wt %	Wt %
0.5	0.01	0.49	0.32
0.25	0.11	6.93	1.90
0.125	59.33	10.64	6.13
0.06	39.84	66.76	23.76
0.03	0.39	14.33	33.65
0.01	0.08	0.32	16.76
0.008	0.02	0.01	7.22
0.004	0.02	0.01	3.69
0.002	0.07	0.28	3.22
0.001	0.06	0.11	2.78
0.0005	0.06	0.11	0.47
0.0002	0.01	0.11	0.10

1. [3 pts] Evaluate the grain-size sorting of the bed samples. Which site(s) are well sorted and which site(s) are not as well sorted?
   Hint: Well sorted samples have a narrow distribution of grainsizes, while poorly sorted samples have a wider grainsize distribution.

2. [3 pts] The sites that are well sorted are lacking fine-grained sediment. Why aren't the fine-grained sediments accumulating on the bed at these locations?

3. [5 pts] Would you suspect that any of the seabed sediments were delivered as aggregates? If so, which site(s)? How would the aggregate's settling velocity compare to individual, non-aggregated particles?
   Hint: Aggregates are clumps of fine grained particles.

4. [5 pts] You are writing a proposal to study sediment resuspension due to tidal currents on the Washington margin. Estimated peak tidal currents reach ~ 70 cm/s during spring tides. Roughly estimate the peak bed shear stress from just this information.

$$\tau^b = \rho_w C_D \overline{U}^2$$

$C_D = 3 \times 10^{-3}$

5. You get funded! And deploy instruments to get a better estimate of the bed shear stress. Simultaneous current data from four current meters at Station 23 result in:

Current Meter Elevation (cm)	Current Max Ebb Flow (cm/s)
23	51.5
54	62.1
71	64.8
101	67.1
251	73

   a. Plot the velocity profiles in Excel and fit a line to your data. Remember that the y-axis should be ln(depth). You do not need to turn in this plot, but you do need it to answer the following questions.
   Hint: It is a GREAT idea to get your plot checked by an instructor or TA before moving on!

   b. [10 pts] From your fitted line and equations provided below, compute the following for max ebb tides:

      z_o =

      u_* =

      U_{100} =

      τ_b =

   Hint: Your new answer for shear stress should be similar to your original estimate!

   The drag coefficient, C_{100}, can be "back-calculated" from the Quadratic Stress Law – what was the effective drag coefficient at this site?

      C_{100} =

The Law of the Wall:
$$\bar{u} = \frac{u_*}{0.41}\ln\left(\frac{z}{z_o}\right)$$

The slope of the profile can be used to obtain u_*:
$$u_* = 0.41\frac{\Delta u}{\Delta \ln(z)}$$

Quadratic Stress Law:
$$\tau^b = \rho_w C_{100}\overline{U_{100}}^2$$

And by definition:
$$\tau^b = \rho_w u_*^2$$

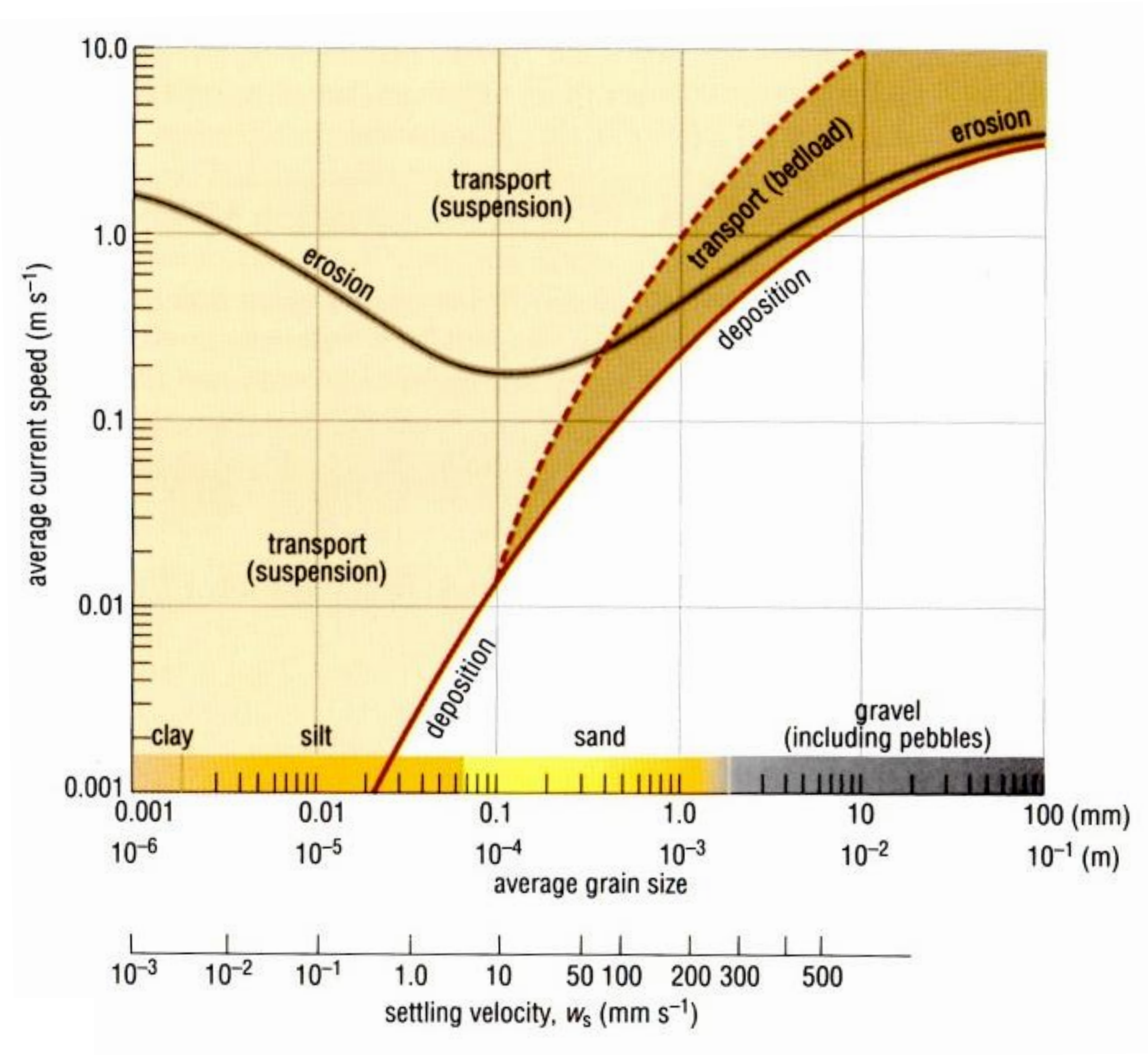
c. [10 pts] In one sentence for each variable, explain what the 5 variables you just found mean. These descriptions should be written for an intelligent audience who know basically nothing about this topic, so break it down!

Ex) Good Answer: W_s is the velocity of a particle as it falls vertically through water due to gravity.

Bad Answer: W_s is settling velocity.

13. [15 pts] Using the Hjulström Diagram below, evaluate whether threshold is exceeded at the three stations.
   a. Plot where each station falls on Figure 1 (labeling each point).
   b. Fill in each cell of the table below with the size description (e.g., coarse sand) and a Yes or No for the transport condition.

Station	D_{50} (cm)	U_{100} (cm/s)	Size Description	Deposition (Yes or No)	Transportation (Yes or No)	Erosion (Yes or No)
Sta. 5	0.014	100				
Sta. 23	0.0088	70				
Sta. 24	0.0044	10				



14. In a few sentences, explain why we as scientists care about where sediment is eroded and deposited in nearshore environments. What do the sediment transport patterns found here suggest about modern controls on this continental shelf's morphology? What can we infer from this information about the future of this coastal environment?

15. In a few sentences, explain why non-scientists may care about our overall conclusions from this study.

References

This lab was created by Robin McLachlan (mclachlan.rl@gmail.edu) of University of Washington in 2016 for OCEAN 320, an undergraduate-level course on coastal oceanography.