Name ___________________________________ 47 Points

5. Stream Sediment

Learning Outcomes

By the end of this assignment you should be able to:

- Describe the relationship between particle size and critical shear stress, particle size and critical velocity, and particle size and critical depth, and explain why these relationships exist;
- Calculate fluvial shear stress and critical depth;
- List reasons why laboratory calculations of critical shear stress, velocity, and depth do not translate directly to real-world situations.

Symbols and Equations

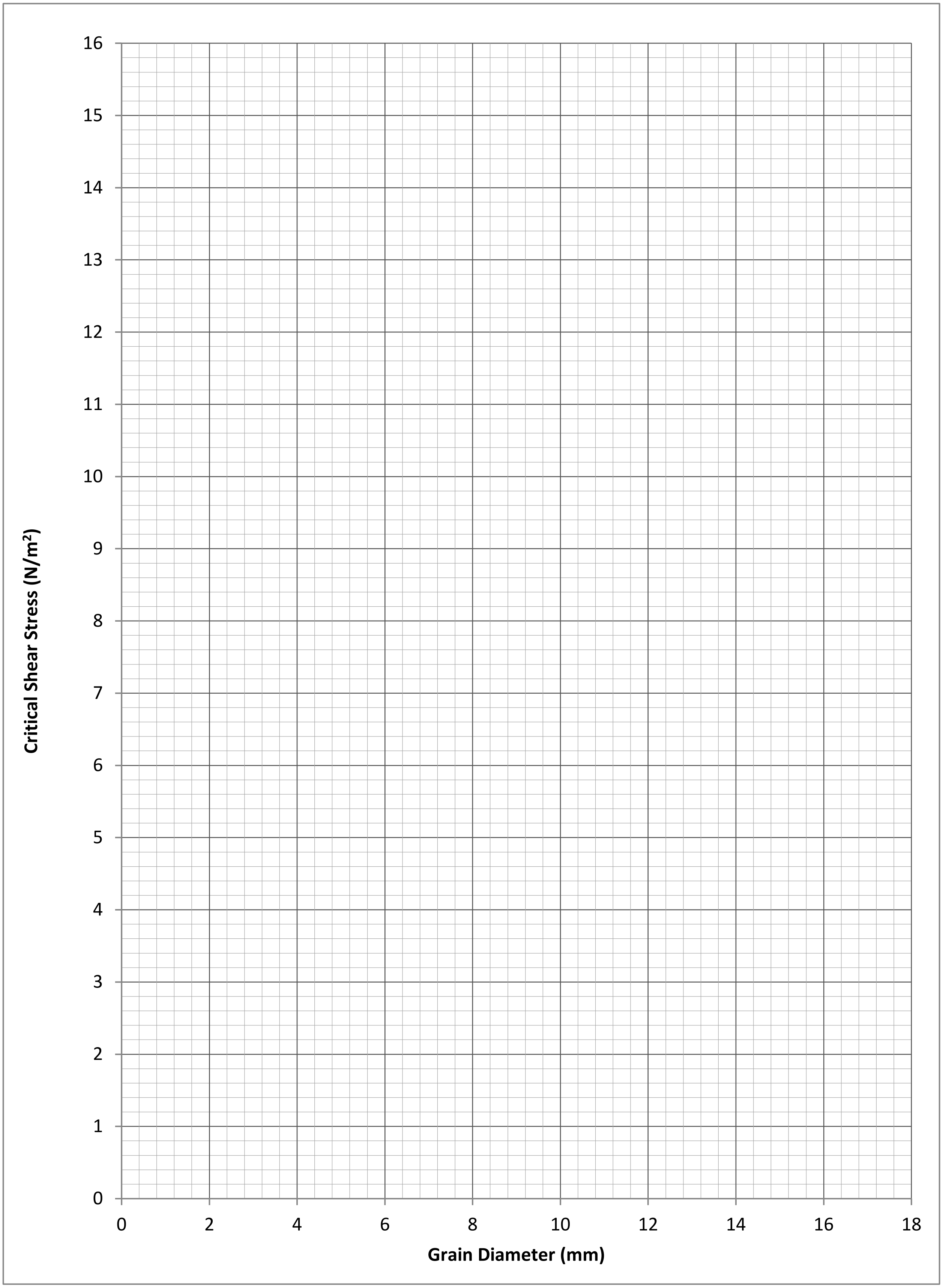
τ = shear stress = $\rho \times g \times \bar{d} \times s$	$\tau_{c\ (Knighton)} = 0.06g(\rho_s - \rho_w)d_s$	$\tau_{c\ (Handout)} = 0.73 \times d_s$
$Q = A \times \bar{v}$	A = cross-sectional area (m^2)	$\bar{v}$ = average velocity
Q = discharge (m^3/sec or ft^3/sec)	τ_c = critical shear stress (N/m^2)	v_c = critical shear velocity (m/sec)
$\bar{d}$ = average water depth (m)	d_s = particle diameter (mm)	s = channel slope (m/m)
ρ = density (kg/m^3)	ρ_s = sediment density = 2650 kg/m^3	ρ_w = water density = 999 kg/m^3 at 15°C
g = gravity = 9.81 m/sec/sec	1 m = 3.281 ft	1 m^2 = 10.76 ft^2

Questions

1. Determine the critical shear stress for the particle diameters listed below. For the column labeled "Julien," look up the values on the last page of the handout *Fluvial Symbols, Constants and Formulas.* For the column labeled "Knighton," use the $\tau_{c\ (Knighton)}$ equation above. For the column listed "Handout," use the $\tau_{c\ (Handout)}$ formula, which is the formula listed on the handout *Fluvial Symbols, Constants and Formulas*. Pay attention to your units. [9]

d_s (mm)	τ_c Julien	τ_c Knighton Eq.	τ_c Handout Eq.
0.063 (very fine sand)	______________	______________	______________
0.26 (medium sand)	______________	______________	______________
0.51 (coarse sand)	______________	______________	______________
1.1 (very coarse sand)	______________	______________	______________
2.1 (very fine gravel)	______________	______________	______________
4.1 (fine gravel)	______________	______________	______________
8.1 (medium gravel)	______________	______________	______________
16.1 (coarse gravel)	______________	______________	______________

2. Graph the relationship between particle diameter and critical shear stress using the values from Question 1. Use a ruler to add a trend line (best fit line) through the center of each set of points. You will have three trend lines on your graph. [9]


Critical Shear Stress (N/m²)
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
0
2
4
6
8
10
12
14
16
18
Grain Diameter (mm)

3. Compare the three sets of critical shear stress values by determining how close the values are to one another as a percentage. Calculate percentages for the smallest and largest particles sizes listed, and for two intermediate particle sizes (your choice). Show your work. For which particle sizes are the three sets of values most similar and for which particle sizes are they most different? Suggest several reasons for why these estimates of critical shear stress are not the same, and for why the estimates might be better for some particle sizes than for others. [6]

4. Enter the critical shear velocity values from the handout *Fluvial Symbols, Constants and Formulas* for the particle sizes listed below. Then determine the minimum cross-sectional area necessary so that the critical velocity won't be exceeded (i.e. no erosion will occur) for each particle size assuming a stream has an average discharge of 3.1 m^3/s (3.1 m^3/s = 100 ft^3/s, which is the approximate discharge of the Tomorrow River at our field site). [4]

d_s (mm)	Critical shear velocity (m/s)	Minimum cross-sectional area (m^2)
0.063	________________	________________
0.25	________________	________________
0.51	________________	________________
1.1	________________	________________
2.1	________________	________________
4.1	________________	________________
8.1	________________	________________
16.1	________________	________________

5. What is the relationship between particle size and critical shear velocity? [1]

6. A stream channel has a slope of 0.0002 m/m, a water temperature of 15°C, and a bed composed of uniform material. Determine the maximum depth at which the channel will remain stable (i.e. no erosion will occur) for the particle sizes listed below using the equation for shear stress and the critical shear stress values from Julien in question 1. [4]

d_s (mm)	Critical depth (m)	d_s (mm)	Critical depth (m)
0.063	______________________	2.1	______________________
0.25	______________________	4.1	______________________
0.51	______________________	8.1	______________________
1.1	______________________	16.1	______________________

7. What is the relationship between particle size and critical depth? [1]

8. Why do larger particles require a greater water depth for entrainment than smaller particles? Why isn't velocity alone sufficient to determine whether particles are entrained or not? [4]

9. Calculate the critical depth for particles with a diameter of 2.1 mm at different slopes assuming a water temperature of 15°C, and a channel composed of uniform bed material. Use the equation for shear stress and the critical shear stresses from Julien listed in question 1. [4]

slope	Critical depth (m)	slope	Critical depth (m)
0.0001	_______________	0.001	_______________
0.0002	_______________	0.002	_______________
0.0005	_______________	0.005	_______________
0.0009	_______________	0.009	_______________

10. What is the relationship between critical depth and slope for a specific particle size? Why does this relationship exist? [2]

11. If we apply the relationships between particle size and critical shear velocity, critical shear stress, and critical depth revealed in this assignment to our field data we might find that the relationships are inaccurate. Particles might get entrained at our field site at velocities, shear stresses, or depths smaller or larger than expected. Provide three reasons other than errors in our field measurements for why this might be the case. [3]