GEOL 332 Froude and Reynolds

The Froude and Reynolds Numbers

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The Reynolds and Froude number do not measure the same thing and cannot be used interchangeably. The Reynolds number measures the degree of turbulence, or random changes in flow direction and/or velocity superimposed on the main downstream movement of water (Richards, 2004). The Froude number relates flow depth to flow velocity, but says nothing about random secondary flow patterns imposed on the downstream movement of water. Despite the differences in these two measures of flow characteristics, they have some things in common. First, both equations include average flow velocity. Second, both equations provide some indication of the energy available for entrainment and transportation of sediment. Large Reynolds numbers indicate turbulent flow, a necessary condition for sustaining sediment in suspension (Richards 2004). The Froude number tends to correlate with different types of bedforms, such as dunes and ripples, and helps identify situations where the energy state of the river changes suddenly, such as in hydraulic jumps (Richards 2004). Third, the Froude number includes the average water depth, while the Reynolds number includes the hydraulic radius. Although the average water depth and the hydraulic radius do not measure the same thing and should not be used interchangeably, in wide shallow channels the hydraulic radius approximates the average depth (Richards 2004). Despite the fact that some similarities exist between these two measures of flow conditions, it is important to remember that they do not measure the same thing and cannot be used interchangeably.

In the Stream Turbulence and Subcritical/Supercritical Flow activities, we determined how a change in a single channel or flow characteristic (e.g. depth or velocity) affected the Reynolds and Froude numbers, while holding other factors constant. Although this is useful for helping you understand the meaning behind your calculated numbers, in reality, rivers rarely experience a change in only one factor. As water flows along a stream channel, multiple factors change simultaneously – a change in channel depth is often accompanied by a change in flow velocity. The objective of this assignment is for you to gain an understanding of how the Reynolds and Froude numbers change along a stream where the only constant is the total discharge.

References

- Richards, K. (2004) Rivers: Form and Process in Alluvial Channels. Caldwell, NJ: Blackburn Press.

Symbols:

Re = Reynolds number = $\overline{v} \times r/\upsilon$	$\overline{v}$ = average velocity (ft/s)	$A = w \times \overline{d}$
F = Froude number = $\overline{v} / \sqrt{(g \times \overline{d})}$	$\overline{d}$ = average depth	P_w = wetted perimeter= $w + 2\overline{d}$
Q = discharge = $w \times \overline{d} \times \overline{v} = a \times \overline{v}$	w = width	r = hydraulic radius (ft) = a/P_w
υ = kinematic viscosity of water = 0.00001076 ft^2/s		g = gravity = 32.2 ft/s/s

1. The following measurements are all from the same river. The discharge at each location is 150 cfs. For each transect, calculate the following.

- flow velocity (rounded to one decimal place),
- Froude number (rounded to two decimal places),
- Reynolds number (with no decimal places).

Then classify the flow conditions as laminar/turbulent and as supercritical/subcritical based on your calculations.

	Transect A	Transect B	Transect C	Transect D	Transect E	Transect F	Transect G
d (ft)	0.4	0.4	0.6	0.8	1.2	2.5	3.5
w (ft)	100	90	80	80	70	60	50
a (ft^2)	40	36	48	64	84	150	150
Pw (ft)	100.8	90.8	81.2	81.6	72.4	65.0	57.0
r (ft)	0.4	0.4	0.6	0.8	1.2	2.3	2.6
v (ft/s)							
F							
Re							
F Class							
Re Class							

Use your answers to question 1 to answer the remaining questions.

2. Cross-Sectional Area and Velocity

a. At a given discharge, as cross-sectional area increases, does velocity increase, decrease, or stay the same? Why?

b. Does the relation between cross-sectional area and velocity hold regardless of channel shape (wide, shallow or narrow, deep)? If not, why not?

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3. Cross-Sectional Area and Wetted Perimeter

a. At a given discharge, as cross-sectional area increases, does the wetted perimeter tend to increase, decrease, or stay the same? Why?

b. Transects F and G have the same cross-sectional area, but different wetted perimeters. Why?

c. Transects C and D have almost identical wetted perimeters but different cross-sectional areas. Why?

d. Does the relation between cross-sectional area and wetted perimeter you listed for part (a) hold regardless of channel shape (wide, shallow or narrow, deep)? If not, why not?

4. Wetted Perimeter and Velocity

a. At a given discharge, as wetted perimeter increases, does velocity increase, decrease, or stay the same? Why?

d. Does wetted perimeter appear to have a significant impact on velocity, or are other factors more important?

5. Cross-Sectional Area and Hydraulic Radius

a. At a given discharge, as cross-sectional area increases, does the hydraulic radius tend to increase, decrease, or stay the same? Why?

b. Transects F and G have the same cross-sectional area, but different hydraulic radii. Why?

c. Transects A and B have the same hydraulic radius but different cross-sectional areas. Does the general relationship between area and hydraulic radius you state in part (a) apply to transects A and B? If not, why not?

6. Hydraulic radius and velocity

a. At a given discharge, as hydraulic radius increases, does velocity increase, decrease or stay the same? Why?

b. Transects A and B have the same hydraulic radius but different velocities. Why?

c. Transects F and G have the same velocity but different hydraulic radii. Why?

7. Channel Shape and Velocity

a. At a given discharge, is flow velocity generally faster in wide-shallow channels or narrow deep channels? Why?

b. Channels F and G have the same cross-sectional area, but Transect F is slightly wider and shallower than Transect G. For just these two transects, does channel shape affect flow velocity? Why or why not?

8. Depth and Velocity

a. At a given discharge, as depth increases, does velocity tend to increase, decrease, or stay the same? Why?

b. Transects A and B have the same depth but different velocities. Why?

9. Cross-Sectional Area and Turbulence (Re)

a. At a given discharge, as cross-sectional area increases, does the degree of turbulence tend to increase, decrease, or stay the same? Why?

b. Transects E and F have the same cross-sectional area, but different Reynolds numbers. Why?

c. Transect A has a larger cross-sectional are than Transect B, but a smaller Reynolds number. Why?

10. Velocity and Turbulence (Re)

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a. At a given discharge, as velocity increases, does turbulence (Re) tend to increase, decrease, or stay the same? Why?

b. Transects F and G have the same velocity but their turbulence differs. Why?

11. Depth and Turbulence (Re)

a. At a given discharge, as depth increases, does turbulence (Re) tend to increase, decrease, or stay the same? Why?

b. Transects A and B have the same depth but their turbulence differs. Why?

c. Transect D is deeper than Transect C, but has a smaller Reynolds number. Why?

12. Hydraulic Radius and Turbulence (Re)

a. At a given discharge, as hydraulic radius increases, does turbulence (Re) tend to increase, decrease, or stay the same? Why? [2]

b. Transects A and B have the same hydraulic radius but their turbulence differs. Why?

c. Transect D has a larger hydraulic radius than Transect C, but a smaller Reynolds number. Why?

13. Velocity and the Froude Number

a. At a given discharge, as velocity increases, does the Froude number tend to increase, decrease, or stay the same? Why?

b. Transects F and G have the same velocity but different Froude numbers. Why?

14. Depth and the Froude Number

a. At a given discharge, as depth increases, does the Froude number tend to increase, decrease, or stay the same? Why?

b. Transects A and B have the same depth but different Froude numbers. Why?

15. Reynolds Number and Froude Number

a. Can streamflow be both turbulent and subcritical?

b. Can stream flow be both laminar and supercritical?