Name ___________________________________ 94 Points

4. Relationships Between Stream Geometric & Hydraulic Characteristics

In assignment 1, you calculated basic geometric characteristics of stream channels and hypothesized how these characteristics might affect stream flow. The first assignment, however, did not include any actual measurements of stream flow. In assignments 2 and 3, you determined how a change in a single channel or flow characteristic (e.g. depth or velocity) affected the Reynolds and Froude numbers (important hydraulic characteristics), while holding other factors such as flow velocity and discharge constant. Although these exercises are useful for helping you understand the meaning behind your calculated numbers and basic relationships between stream characteristics, 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 stream geometry and flow characteristics may 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.

Learning Outcomes

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

- Calculate the Froude and Reynolds numbers and classify flow as either laminar or turbulent and as either subcritical or supercritical;
- Describe relationships between different channel geometric characteristics at a constant discharge;
- Describe relationships between channel geometric and stream flow characteristics at a constant discharge; and,
- Explain why these relationships exist.

Symbols & Equations

Re = Reynolds number = $\bar{v} \times r/\upsilon$

F = Froude number = $\bar{v} / \sqrt{(g \times \bar{d})}$

Q = discharge = $w \times \bar{d} \times \bar{v} = a \times \bar{v}$

υ = kinematic viscosity of water = 0.00001076 ft^2/s

$\bar{v}$ = average velocity (ft/s)

$\bar{d}$ = average depth

w = width

$A = w \times \bar{d}$

P_w = wetted perimeter= $w + 2\bar{d}$

r = hydraulic radius (ft) = a/P_w

g = gravity = 32.2 ft/s/s

1. The measurements in the table below are from seven closely-spaced transects along the same river. The discharge at each location is 150 cfs. For each transect, calculate the: [24]
   - 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	3.0
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	56.0
r (ft)	0.4	0.4	0.6	0.8	1.2	2.3	2.7
v (ft/s)							
F							
Re							
F Class							
Re Class							

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

Cross-Sectional Area and Velocity

2. At a given discharge, as cross-sectional area increases, does velocity increase, decrease, or stay the same? Why? [2]

3. Does your answer to question 3(b) in Assignment 1 match the answer you gave above in question 1? [1]

4. Does the relationship between cross-sectional area and velocity hold regardless of channel shape (wide, shallow or narrow, deep)? Explain. [2]

Cross-Sectional Area and Wetted Perimeter

5. At a given discharge, as cross-sectional area increases, does the wetted perimeter tend to increase, decrease, or stay the same? Why? [2]

6. Why do transects F and G have different wetted perimeters when their cross-sectional areas are the same? [1]

7. Why do transects C and D have almost identical wetted perimeters when their cross-sectional areas are different? [1]

8. Does the relationship between cross-sectional area and wetted perimeter you listed for question 5 above hold regardless of channel shape (wide, shallow or narrow, deep)? Explain. [2]

Wetted Perimeter and Velocity

9. At a given discharge, as wetted perimeter increases, does velocity increase, decrease, or stay the same? Why? [2]

10. What impact did you hypothesize wetted perimeter had on velocity in Assignment 1, question 5(b)? [1]

11. Does your answer in this assignment match your answer from Assignment 1? If not, why not? [2]

12. Does wetted perimeter appear to have a significant impact on velocity, or are other factors more important? [1]

Cross-Sectional Area and Hydraulic Radius

13. At a given discharge, as cross-sectional area increases, does the hydraulic radius tend to increase, decrease, or stay the same? Why? [2]

14. Transects F and G have the same cross-sectional area, but different hydraulic radii. Why? [1]

15. 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? [2]

Hydraulic radius and velocity

16. At a given discharge, as hydraulic radius increases, does velocity increase, decrease or stay the same? Why? [2]

17. Transects A and B have the same hydraulic radius but different velocities. Why? [1]

18. Transects F and G have the same velocity but different hydraulic radii. Why? [1]

19. What impact did you deduce hydraulic radius should have on flow resistance in Assignment 1, question 6(b)? [1]

20. Do your answers in this assignment agree with your answer in Assignment 1? If not, why not? [2]

Channel Shape and Velocity

21. At a given discharge, is flow velocity generally faster in wide-shallow channels or narrow deep channels? Why? [2]

22. 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? [2]

23. Does your answer in Assignment 1 question 7 match your answer in this assignment? If not, why not? [1]

Depth and Velocity

24. At a given discharge, as depth increases, does velocity tend to increase, decrease, or stay the same? Why? [2]

25. Transects A and B have the same depth but different velocities. Why? [1]

Cross-Sectional Area and Turbulence (Re)

26. At a given discharge, as cross-sectional area increases, does the degree of turbulence tend to increase, decrease, or stay the same? Why? [2]

27. Transects E and F have the same cross-sectional area, but different Reynolds numbers. Why? [1]

28. Transect A has a larger cross-sectional are than Transect B, but a smaller Reynolds number. Why? [1]

29. What impact did you hypothesize cross-sectional area had on turbulence in Assignment 2, question 1(d)? [1]

30. Does your answer in Assignment 2 agree with your answer in this assignment? If not, why not? [2]

Velocity and Turbulence (Re)

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

32. Transects F and G have the same velocity but their turbulence differs. Why? [1]

33. Does your answer to Assignment 2 question 1(e) match your answer in this assignment? If not, why not? [2]

Depth and Turbulence (Re)

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

35. Transects A and B have the same depth but their turbulence differs. Why? [1]

36. Transect D is deeper than Transect C, but has a smaller Reynolds number. Why? [1]

Hydraulic Radius and Turbulence (Re)

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

38. Transects A and B have the same hydraulic radius but their turbulence differs. Why? [1]

39. Transect D has a larger hydraulic radius than Transect C, but a smaller Reynolds number. Why? [1]

Velocity and the Froude Number

40. At a given discharge, as velocity increases, does the Froude number tend to increase, decrease, or stay the same? Why? [2]

41. Transects F and G have the same velocity but different Froude numbers. Why? [1]

42. Does your answer to Assignment 3 question 9 match your answer in this assignment? [1]

Depth and the Froude Number

43. At a given discharge, as depth increases, does the Froude number tend to increase, decrease, or stay the same? Why? [2]

44. Transects A and B have the same depth but different Froude numbers. Why? [1]

45. Do your answers in Assignment 3 questions 7(a) and 8 regarding the relationship between depth and the Froude number agree with your answer in this assignment? [1]

Reynolds Number and Froude Number

46. Can streamflow be both turbulent and subcritical? [0.5]

47. Can stream flow be both laminar and supercritical? [0.5]

Pools and Riffles

48. Based on all your above answers, predict how the characteristics of pools and riffles should compare to one another in the real world by indicating which location should have higher or lower values for each characteristic. In the last column, indicate the numbers of the questions above with answers that support your prediction. You will most likely end up listing more than one question for each characteristic. [8]

	Riffle	Pool	Questions supporting answer
Width (w)	Wide	Narrow	
Depth ($\overline{d}$)	Shallow	Deep	
Cross-sectional area (a)			
Wetted perimeter (Pw)			
Hydraulic radius (r)			
Velocity ($\overline{v}$)			
Reynolds number (Re)			
Froude number (Fr)			