Geology 202
Lab 5
Basic River Mechanics
Fall, 2006

Name:_________________________

Need:

- 2 flow meters
- 2 measuring tapes (100')
- sight levels (4)
- stadia rods
- flagging
- USGS water supply paper 1849 (Barnes, 1967)

General

In this lab, we will observe some of the processes operating along a meandering river and measure some of the hydrological parameters of this river. We will work along a reach of the Alplaus Creek, which drains southward from the Glenville Hills and joins the Mohawk River about 3 km north of campus.

The velocity of water in a channel represents a balance between factors causing water to flow and factors that resist fluid flow. As flow velocity increases, there is a transition from laminar to turbulent flow (Ritter et al., 2002). The **Reynolds number (Re)** is a hydrologic parameter that represents the ratio between driving and resisting forces. It is useful in distinguishing between turbulent and laminar flow. Re values less than 500 are indicative of laminar flow whereas values greater than 500 indicate turbulent flow. The **Reynolds number** is calculated as:

$$Re=VR\rho/\mu$$

where V is average flow velocity, **R is hydraulic radius**, r is the density of water, and μ is molecular viscosity. We will determine average velocity in our calculations of stream discharge (see below).

Hydraulic radius or R is the ratio of A/P, where A is the area of the cross section through which stream flow is occurring and P is the wetted perimeter (Ritter et al., 2002), which is simply the perimeter of the cross section through which the stream is flowing. Empirically, it has been determined that a rough estimate of R is to simply use average water depth of the channel; this is a convenient short cut that we'll use.

So to calculate an Re value, we need to measure the cross section of the stream, which we will do to measure discharge. As we do this, we will also measure flow velocity every 1-2 feet; this will enable us to calcuate an average velocity. The other two variables are ρ and μ, and if we assume normal stream flow and not a turbid debris flow, these are constants that vary only slightly with temperature.

The other equation that is basic to fluvial geomorphology is Manning's equation, which is a ratio of driving to resisting forces operating along a stream. **Manning's equation** is:

$$\mathbf{V=(1.49/n)R^{2/3}\,S^{1/2}}$$

where V is velocity, n is channel roughness, and S is slope. According to this equation, the driving forces on a stream are hydraulic radius and slope, and resisting forces can be simplified to the term “channel roughness”, or Manning’s n. Slope has an intuitively obvious affect on stream flow velocity. Hydraulic radius affects stream flow because a large hydraulic radius places a larger proportion of stream flow far from the banks of the stream, and it is the banks that act to slow stream flow. In contrast, an infinitely wide and shallow cross section will yield a very low hydraulic radius, which places a very high proportion of a streams flow in proximity to a stream bank. Manning’s n value can be estimated from Barnes (1967), which provides photographs of streams with varying degrees of roughness as calculated from Manning’s equation. Field geomorphologists use Barnes (1967) to estimate Manning’s n so that Manning’s equation can be used to estimate average flow velocity.

Objectives

The purpose of this lab is to give you the opportunity to work with some of the basic equations that describe flow in a natural stream. While details of the equations that we will be working with derive from the from the field of civil engineering, many consulting geologists have to work with Manning’s equation and Reynolds numbers when working in the fluvial environment. For example, consulting geologists are often hired to evaluate the impact of rerouting a stream or of lining its banks in concrete as part of urban development. If channel roughness (Manning’s n) is not maintained along the rerouted reach of the stream, one of the downstream effects of such development can be increased channel erosion which can lead to bank collapse and other unintended consequences.

For this lab, we will:

1. determine the discharge at a riffle and pool along Alplaus Creek.
2. use values of average velocity and depth derived from our discharge calculations to calculate Reynolds numbers for both the pool and riffle cross section to see which are dominated by laminar flow and which are dominated by turbulent flow.
3. Measure slope and estimate Manning’s n to calculate an estimate mean flow velocity to compare with our measured flow velocity.
4. To examine exposures along stream banks and postulate their origin.
5. Sample stream water to calculate to estimate the rate of chemical denudation of the Alplaus River Drainage Basin

Part 1. (in field)- Measurement of Cross Sectional Area and Velocity; Estimation of Bed Roughness

Because the channel is irregular and because velocity varies with depth and channel position, it is necessary to take both velocity and depth measurements across the channel at regular intervals. To accomplish this:

1- Stretch a measuring tape across the river and fasten the ends of the tape to the wooden stakes.
2- For cross section A (riffle), measure velocity in ft/sec and water depth in feet every 2 feet across the channel. Use the rod that supports the flow meter to measure water depth to the nearest 0.1 feet (each gradation in the rod

represents 0.1 feet). Measure the current velocity at a depth of 1/2 the water depth at exactly the same place that you measured your water depth measurements. Simply adjust the position of the flow sensor to the desired depth. Record all of your data in your field notebooks. ***Be sure to place the strap of the current meter (=expensive!!) over your head!!***

3- For cross section B (pool), follow step #2 (above) but **ALSO** measure flow velocity every 0.2 feet of water depth at 3 places—several feet from each bank and in the middle. Start at 0.2 ft above the bottom and work your way up, adjusting the position of the flow sensor.
4- Using the sight levels and stadia rods, measure channel slope for both the riffle and pool cross sections. This should be done at least 3 times by different team members, and results should be averaged.
5- Using the U.S. G.S. Water Supply Paper 1849, estimate the bed roughness for the riffle and pool sections.

<u>Part 2 (on your own!)- Calculations and Graphis</u>

1- Discharge

Each team will provide me with their data, and I will compile it all and post it on the web. We will go over the calculation of stream discharge in class, and the derivation of mean velocity.

2- Re and Manning's equations

I will post each team's data on the web. Using these data, calculate Re values for both riffle and pool, and calculate stream velocity using Manning's equation. Refer to Ritter et al. (2002) for the equations and significance of these indices. For Reynolds numbers, you will need to know the density and viscosity of water. For viscosity use the value for 5°C of 0.0102 lb/sec*ft; for density use the value for 5°C of 62.42 (lbs/ft^3). Again, for hydraulic radius (R) use the mean depth of your channels. All of these calculations must be included on a spreadsheet using EXCEL—develop one spreadsheet for the riffle and one for the pool.

3- Contouring your POOL cross section velocity data (see Fig. 6.3, p. 192 of Ritter et al., 2002)

Once you have made your two cross sections in EXCEL (we will go over this in class), contour your flow velocity data for the POOL section (ONLY).

<u>Part 3 (Reports)</u>

1. **Figures to Include.** Two cross sections (each a separate figure), one for the riffle and one for the pool. Velocity values must be labeled in their correct position. The pool cross section must have velocity contours (we will decide upon a contour interval in class). These figures will be made in EXCEL, so use the custom footer command to place your figure caption *at the bottom of* the figure.
2. **Tables to Include.** All data and calculations for each cross section (riffle and pool) will go on a separate Table made in EXCEL. Again, use the custom

header command to place your Table caption *at the top* of the Table (centered).

3. **Text**. For this lab, we will not follow the standard lab format. Instead, I would like you to discuss the following on a type-written page or two.
    - **a.** Whether Reynold's numbers suggest laminar or turbulent flow for each cross section, and whether these agree with what you predicted in the field (see Ritter et al., 2002, p. 191).
    - **b.** Whether the discharge through the two cross sections agrees with one another (±20%) or whether one of the cross sections has a greater discharge than the other, and what might cause this difference.
    - **c.** Compare the average flow velocity that you calculated using Manning's equation with the average flow velocity that you measured with the flow meter. How well do these agree and what might be responsible for differences.
    - **d.** Interpret your contoured velocity data for the POOl cross section. Why does it look as it does? What is the underlying control on the variation of stream flow velocity data with depth and with distance across a stream channel.
    - **e.** What is the rate of chemical denudation (in mm per 1000 years) of the Alplaus River Drainage Basin (show all of your work)? Why is this an underestimate of the total rate of basin denudation? How much higher could the total rate be?