Geomorphology Lab: Stream Flow

Destination: Balch Creek in Portland's wonderful NW district. The creek is named after Denholm Balch who lived near the creek and in 1859 was the first person to be legally tried and hanged in Portland. He murdered his son-in-law.

Things to bring: Suitable clothing and footwear for a Portland park in the spring. You will need a pencil and a hard surface to write on. (Field rule 1 - never use ink in the field, it bleeds on wet or damp paper).

Purpose: To measure and calculate some physical characteristics of a stream. Balch Creek is a good example because it accessible, relatively small and safe making it suitable for such an exercise. Although the Columbia or Willamette may be more exciting fluvial features, the time and effort to make measurements in those rivers far exceeds what extra we might learn. That's the nice thing about physics. If you understand the fundamental processes, the results can be applied to other, perhaps more difficult, situations.

The ultimate reference: Rantz and 16 others, 1982: Measurement and computation of streamflow: Volume 1. Measurement of Stage and Discharge; and Volume 2. Computation of Discharge. U.S. Geological Survey Water Supply paper 2175, 631 pp.

The Department of Interior's U.S. Geological Survey (USGS) is the agency responsible for monitoring the nation's stream flow and ground water levels. This is not to say that other state and federal make similar measurements, but the USGS Water Resource's Division is considered the lead agency in the subject. For the Oregon District office, see, http://oregon.usgs.gov/

FYI: If you ever want an estimate of stream roughness without trying to measure it, check out the following reference. It is like a Petersen's Field IdentificationGuide, but for channel roughness: Barnes, Jr., H., 1967: Roughness characteristics of natural channels. U.S. Geological Survey Water Supply Paper 1849, 213 pp.

Assignment: The field work will answer questions 1-3, 11, and the remaining questions can be done at home. However, read all questions prior to collecting the field data, it will help you guide your field effort. This is like the real thing. One starts develops a field plan, completes the data collection, and typically analyzes the data elsewhere.

Reports will be typed (font 11 pt and larger) and each answer will follow the numbering system of the questions and be in consecutive order. For mathematical calculations, where one needs to "show your work", neat handwritten calculations are acceptable. These situations are denoted with an asterisk,*. Neatness counts and all pages need to be stapled. Graphs need to be adequately labeled including axis labels with units. All features in a graph or drawing must be

identified. Be careful of units, make sure that are consistent. Finally, pay attention to significant units. Your book will be a resource.
(81pts)

Measurements of stream velocity

1. *Sketch (10pts).* Make a rough plan-view sketch of the stream channel in the vicinity of the measurement cross-section. Include about 2 meters above and below our cross-section. Note channel shape, shallow areas in the water, where rocks might break the water surface, areas of fast versus slow flow, where plants might be interfering with the flow, identify features drawn and flow direction. Include where the floating method was performed (start and stop locations) and where the measurement cross-section is located. Redo the sketch at home and include it in the report.

2. *Floating method (5pts).* Approximate the speed of water flow using a leaf or other debris that floats on the surface. Your field notes should include, elapsed time, and distance traveled. In your report include these figures for each run, the average for all runs and the average flow speed for all runs.

3. *Current meter.* The group will set up a cross-section and measure the flow velocity using the current meter at multiple positions across the stream. See Figure 1. Flow measurements are made at 0.6H from the surface where H is total depth. Record distance across stream, depth and velocity, at each measurement location using the format below. The discharge will be calculated later. Your field notes should be arranged as,

Site.	Distance	Depth	Velocity
1.			
2.			
3.			
etc.			

(2 pts) Why do you think we measure at 0.6H and not, say, at 0.5H?

4. *Discharge calculation (15pts).* The approach towards calculating discharge is to use,

$$Q = VA,$$

where Q is the discharge in m^3/s, V is velocity in m/s, and A is the area in m^2. The specific units are not important as long as they are consistent and in the metric system. To calculate the discharge, we divide the flow cross-section into subsections (Figure 1), and measure the velocity and area for each subsection. The discharge is calculated for each subsection and summed to estimate the discharge of the whole cross section.

$$Q = \sum_1^n q_i = \sum_1^n v_i a_i$$

where q_i is the discharge, v_i, is the velocity and a_i is the area of subsection, i. The area is determined by the depth and the width of each cross-section,

$$a_i = d_i \frac{(b_{i+1} - b_{i-1})}{2}$$

where, d, is the depth at position, i, and, b, is the horizontal distance to that position from an arbitrarily chosen origin (Figure 1). Thus, q_i, is estimated by,

$$q_i = v_i \, d_i \frac{(b_{i+1} - b_{i-1})}{2}$$

For the cells at each end of the cross-section, where i+1 or i-1 do not apply, use the following scheme. At the start use,

$$q_1 = v_1 \frac{d_1}{2} \frac{(b_2 - b_1)}{2}$$

and at the other side,

$$q_n = \frac{v_n}{2} \, d_n \frac{(b_n - b_{(n-1)})}{2}$$

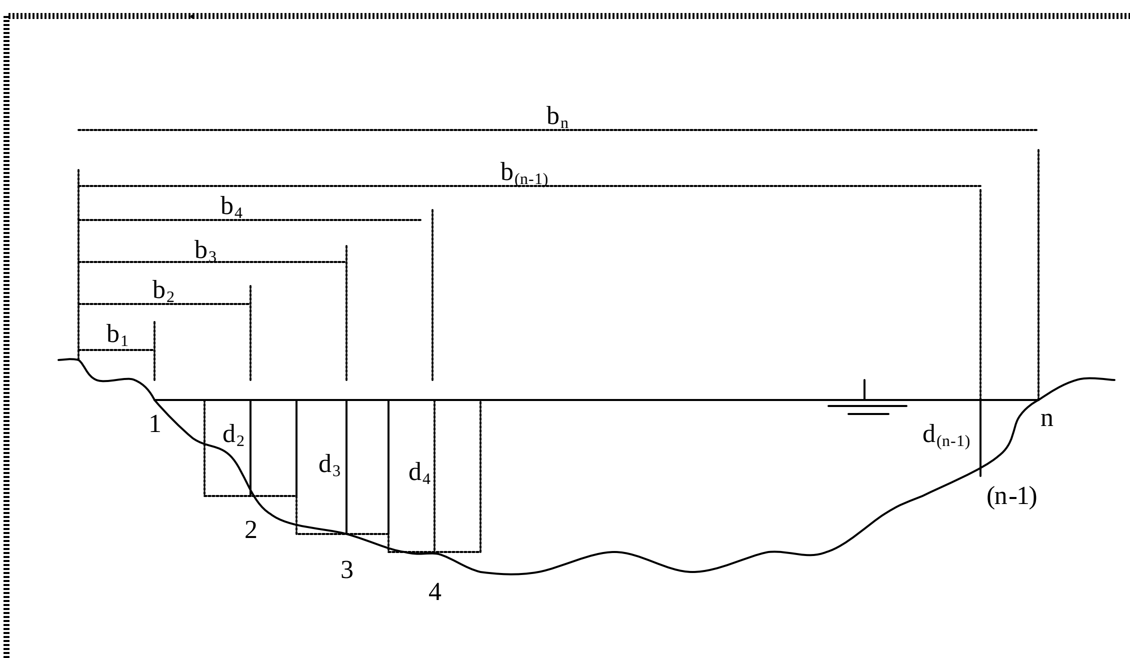


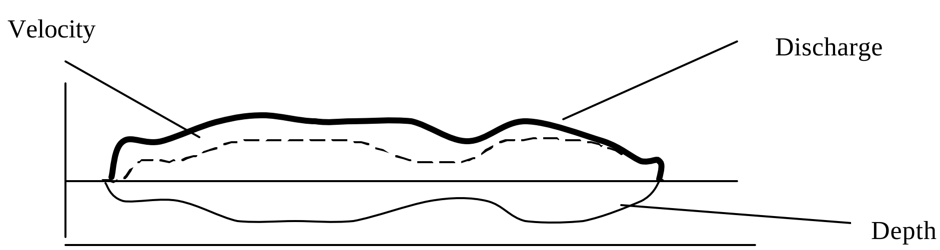
Figure 1. Definition schematic of a stream cross-section for calculating discharge
Taken from Rantz et al., 1982..
Explain how you calculated the values of width at each end of the cross-section

Create a table of measured and calculated values for the report using the following format. It will be very helpful to use a spreadsheet for both the calculations and producing the table for the report. Make all units cm and s.

Loc.	Distance	Depth	Width	Area	Velocity	Discharge
1.						
2.						
3.						
etc.						

At the bottom of your table, provide figures for total area and stream discharge. Also convert the total area and total stream charge to m^3 and $m^3\ s^{-1}$.

5. *Plot (10pts)*. From your table of values, plot the results of discharge, velocity, and stream depth with distance across the stream on the same graph. Make the plot such that the water surface is zero and depth is negative (drops down). Plot depth and width at the same scale to help you with (8) below. On this same plot, include velocity and discharge. You may wish to rescale velocity and discharge to make them fit better on the graph. Ask, if you don't know what rescale means.



This is what the form of the plot will look like. Of course, you will have to add tick marks, labels, units, and a legend of your choice.

6. *(5 pts)* Discuss the plot in reference to friction of the channel walls and observations of flow in the field (sketched in figure 1). Can you explain the variation of flow velocity and discharge?

7. *(2 pts)* Determine the average velocity of the stream from your calculated value of discharge and area in question (4). Do you know why we use this value rather than just the average of all the measured velocities?

8. *(10 pts)* Using the Manning equation, calculate the velocity of the stream. Obtain slope from the map, using the slope from the Thurman Bridge to the crossing of the city boundary line. For the hydraulic radius, use the area calculated in question (4) and the wetted perimeter estimated from your plot. You will need a pair of dividers to measure along the channel bottom. For n, use a value of 0.06 (mountain stream). Compare that to the velocity one obtains from a glass surfaced channel (0.01). Show your work* Manning's equation for metric units, simply replace the constant 1.49 with 1.0.

9. *(5 pts)* Compare all velocities (leaf, discharge, Manning {where, n = 0.06}) for the stream. Which value is best for average stream velocity and why? Include a short discussion of why a difference in values exists.

10. *Hydraulic characteristics*. Assume the molecular viscosity of the water is, 1.31×10^{-3} kg $s^{-1}m^{-1}$, and its density is 1000 kg m^{-3}. Note that specific weight is merely the density times gravity. Use the values for velocity as calculated in (7). Do not use depth in (a) or (b), use hydraulic radius.

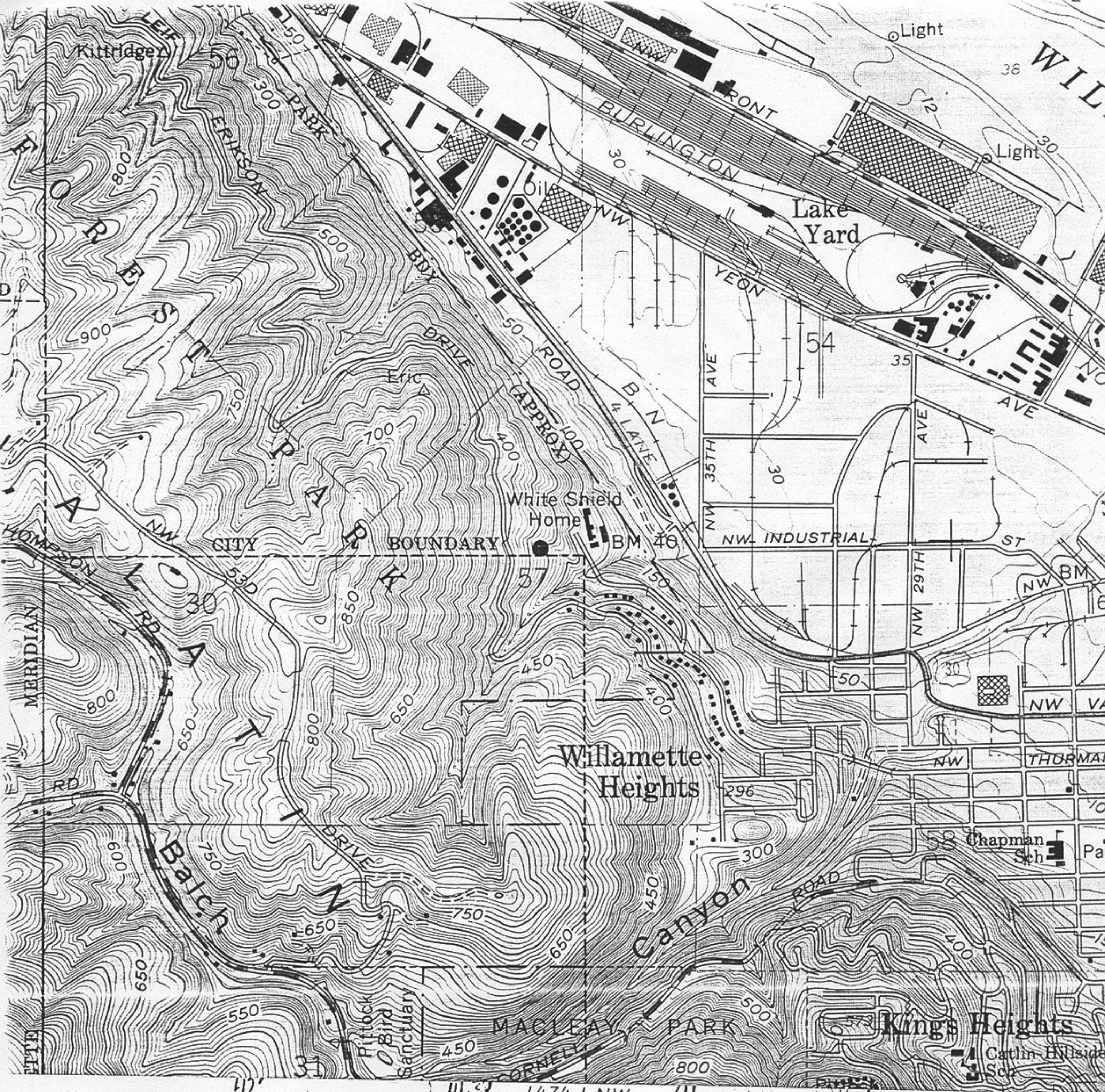
   a. *(5pts)* Is this stream flow laminar or turbulent? Show your work including how the units cancel.

   b. *(5pts)* Is the flow considered tranquil, critical, or rapid (shooting) flow? Show your work including how the units cancel.

   c. *(5 pts)* Calculate the stream power, using the same slope as found in question 8. Show your work including how the units cancel.

11. *(2pts) Paleofloods*. What was the size of some of the paleofloods that moved the surrounding rock? Measure the size of the largest cobble or boulders in or near the stream you can find. If the rock is not spherical take an average of the dimensions. What was the velocity of the water needed to move this rock? Use the top curve in the family of Hjulström curves. If the rock is larger than the graph allows, extrapolate the curve.

12. *(2pts) Sinuosity*. What is the sinuosity of the stream from the Thurman Bridge to the crossing of the city boundary line? Show the values used to calculate the sinuosity. It is calculated by dividing the path length of the stream by the length of a straight line connecting the starting and ending points.



SCALE 1:24 000

1 ½ 0

1000 0 1000 2000 3000 4000 5000 6000 7000 FEET

1 .5 0 1 KILOMETER

CONTOUR INTERVAL 10 FEET

NATIONAL GEODETIC VERTICAL DATUM OF 1929

DEPTH CURVES AND SOUNDINGS IN FEET—COLUMBIA RIVER DATUM

SHORELINE SHOWN REPRESENTS THE APPROXIMATE LINE OF MEAN HIGH WATER

THE MEAN RANGE OF TIDE IS APPROXIMATELY 2 FEET

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