ESS 314
Lab 3, Erosion.
Due next Friday.

Please submit your write-up, the data, and your graphs STAPLED together.

We use the free version of Google Earth for this lab. It is a little buggy, but can do everything we want. Talk to someone next to you, or to me, if you are not familiar with Google Earth software.

Google Earth tips on making and adjusting a path:
1. To make a path: click on either the path icon at the top of the Google Earth window, or under the "Add" menu, click on path.

2. A pop-up window allows you to give the path a name, and change its color, width, units, etc.

3. To adjust a given path that you have already saved, click on the path name in the Places menu on the left option bar, and then click on the "Properties" option under the "Edit" option on the options bar.

4.The path properties window will pop up, and the points on the path will get highlighted. You can "click and hold" on each existing point to move it. You known you can grab a specific point when it changes color. The currently active point is also highlighted in a different color.

5. To create a new point in the existing path, click on the nearest point up-path from where you want to add a new point. You next left-mouse click will add a new point at the location of the mouse crosshairs.

6. To extend an existing path, click on the last point in the existing path. Subsequent left-mouse clicks will add new points to the end of the existing path.

7. When you are done working on creating the path, click "ok" in popup path.

Google Earth tips on looking at the elevation profile:

1. Select the path you want in the Places menu on the left of the screen
2. Under the "Edit" menu option, select "Show Elevation Profile".
3. Clicking on the Elevation Window and moving the mouse will move a big red arrow in the map window, and allow you to see where on the map you are.
4. You will take your data from this elevation profile. OR (and much better and easier) you can download this data into a .kmz file and convert it directly into elevation-distance data (see next section).

Converting a Google Earth path into elevation-distance data:

Once you have made your paths in Google Earth, you can convert them to an elevation distance data set in the following way.

1. Right-click on the path name in the places panel.
2. Pick “Save place as” option.
3. Save the file to a place you can find again. It will be a .kmz file.
4. To convert this, we need a third party application
5. Open a web browser and go to http://www.gpsvisualizer.com/convert_input
6. You can upload your .kmz file
7. Ask for it to determine distance and elevation (choosing the 30m DEM, or best available source for the DEM data)
8. Click on the “convert button”. This will take you to a page with an option to either download the data or you can just cut-and-paste from the screen.

PART I: ELEVLATION VS. DISTANCE PROFILES FOR THE QUEETS RIVER

1. Put placemarks at the following places

Mouth of the Queets: 47°32'16.28"N, 124°21'15.87"W
Service Falls: 47°45'26.81"N, 123°39'30.86"W
Source of the Queets: 47°47'0.63"N, 123°37'12.51"W

(Feel free to adjust them if you think it would be better)

2. Make a coarse-scale elevation profile.
a. Zoom out so you can see the full Queets river.
b. Click on the “set path” icon
c. Make a coarse-scale path that follows the river roughly. Start at the Queet’s river mouth. Using about 10 points between the mouth of the Queets and Service Falls, and about 10 points between Service Falls and the source. Do not worry about hitting the river exactly at a first pass – you can adjust it later.
d. Name the path something useful like “Queets coarse-scale”
e. Now adjust the points so they hit the river- or streambed exactly. You can do this by clicking on the points and moving them with the mouse. You will likely need to zoom to small scale.
f. Under “edit” click on “show elevation profile”

g. Convert your river surface points point to elevation vs. distance. **See notes above on how to do this.** Make sure all your points that sit on the river channel. You don't want to knick the edge of a hillside and have a river that flows uphill.

n.b. If you have a path that you have save in the places panel, you can reactivate it and edit it, by right-clicking on the path and picking "show info" (on a Mac), or "preferences" (on a PC)

3. Make a fine-scale elevation profile.
a. You can copy and paste the coarse-scale path. Rename it something like "Queets_fine".
b. With this new path you can add points at fine scale. You can add a point by clicking on the existing point just up-path, and use the crosshairs to add a point. You can move a point by clicking on it.
c. Add as many as you need – perhaps a hundred or more, mapping out the river as closely as you can.
d. Take readings of elevation & distance making sure you take them only from the points that sit on the riverbed.

n.b. If you have a path that you have save in the places panel, you can reactivate it and edit it, by right-clicking on the path and picking "show info" (on a Mac), or "preferences" (on a PC)

Analyses:

You should now have data in the form of elevation of the riverbed as a function of distance upstream from the mouth of the Hoh.

However from the theory you want to plot the graphs as a function of distance going in the other direction.

I. For both the coarse- and fine-scale elevation profiles, calculate elevation as a function of downstream distance from a) the source of the Queets, and b) Service Falls.

II. Show these four plots of elevation vs. distance (on a single piece of linear graph paper, or on a single plot using suitable graphing software **but be careful you use graphing software correctly: don't just plot a jiggly line through all the points, or fit a 4^{th} order polynomial without thinking. Make sure the analysis is appropriate for the situation and ask if you don't know).**

III. Show the same plots on semilog axes (i.e., height vs. Log(L/x))

More guidance on making graphs in this lab:

0. If you choose physical graph paper, you can download pdfs of the appropriate graph paper on the class website

<u>**1. ALWAYS LABEL AXES CLEARLY.**</u>

2. Choose axis limits so that the graph will cover the paper.

3. Unless otherwise stipulated, draw straight lines from point to point. 4. If you think the data ought to be a straight line on physical grounds, put a clean `best-fit' single straight line through the data.

5. Make sure you understand the log graph paper. Ask if not.

Write short answers to the following questions:

1) Is there a significant qualitative difference to the elevation profiles when detailed meandering is taken into account?
2) How well does the river profile theory work?
3) Why you think the river behavior changes at Service Falls.

PART II: VALLEY CROSS-SECTIONS FOR THE BOGACHIEL AND HOH RIVER.

Put place marks at:
Point A 47°49'13.00"N, 123°55'3.99"W
Point B 47°54'40.35"N, 123°58'2.12"W

These two points straddle both the Hoh and Bogachiel rivers. Make sure you know which is which.

Make a path from point A to point B with many points. Look at the elevation profile across the adjacent Hoh and Bogachiel River valleys along the line on your map.

Generate a plot of this cross section, either by doing a screen grab, or taking some data points from it, and plot them on graph paper, or in excel. **Hand in this plot.**

Notice the distinctly different shape of each valley. Follow each river to its source. What do you find? Discuss why you think the valley shapes are so different.

Summary of the lab:

For the whole lab there should be three graphs submitted, together with your answers and data.

1) linear graph paper (or digitial plot) with the four Queets profiles on it.
2) semilog graph paper (or digital plot) with the four Queets profiles on it.
3) linear graph paper (or digital plot) of the cross-section through the Hoh and Bogachiel valleys.

Theory

This lab will allow you to test the simple theory of the downstream altitude profile of a river.

First, here is a review of the physics for the profile of a river. We start with two empirical relations (see attached figures):

(1) The drainage area A upstream of a distance x from the head of a river is proportional to the square of x:

$$A \propto x^2$$

The attached figure demonstrates that this holds for 8 orders of magnitude in the size of x and is thus a very good approximation.

(2) The width W of a river at any point along its length is proportional to the square root of the river discharge (mass flux) Q.

$$W \propto \sqrt{Q} \quad \Rightarrow \quad Q \propto W^2$$

If D is the depth of the river and V is the flow velocity, then the flux is

$$Q = VDW$$

Thus

$$W^2 \propto VDW \quad \Rightarrow \quad W \propto VD \quad \text{or} \quad V \propto \frac{W}{D}$$

which states that the river velocity is proportional to its aspect ratio. The physical basis for this observation is not yet understood.

We then assume the rate of precipitation P feeding water into the river is uniform. Then conservation of mass implies that

$$Q = AP \propto Px^2$$

A reasonable physical assumption is that rate E at which the river erodes its bed at any x is equal to the "stream power" divided by the width over which this power acts to abrade the bed. The stream power is the rate at which gravitational energy is released as the water flows downhill and is proportional to the flux times the bed slope. Thus

$$E \propto \frac{Q\frac{dh}{dx}}{W} = \frac{Q}{W}\frac{dh}{dx}$$

where h is the altitude of the river bed.

The change in river altitude with time is the difference between its uplift rate U and the erosion rate E. If the river profile is in steady state, its altitude at any point is constant and

$$U = E$$

The above relations and some simple algebra lead to the equation

$$\frac{dh}{dx} = -C\frac{1}{x}$$

where

$$C = \left[\frac{KU}{\sqrt{P}}\right]$$

and K is a parameter that absorbs all the proportionality constants. Since

$$\frac{d}{dx}\log_e(x) = -\frac{1}{x}$$

the solution to the above differential equation is

$$h = -C\ \log_e(x) + \text{constant}$$

If $h=h_0$ at $x=L$, the constant = $h_0 + C \log_e(L)$. Thus

$$h = h_0 - C(\log_e(x) - \log_e(L)) = h_0 - C\ \log_e\left(\frac{x}{L}\right)$$

Noting that $\log_e(x) = \log_e(10)\ \log_{10}(x) = 2.303\ \log_{10}(x)$, we can finally write

$$\boxed{h - h_0 = 2.303\left[\frac{KU}{\sqrt{P}}\right]\log_{10}\left(\frac{L}{x}\right)}$$

where h is the river altitude above its outlet level h_0 (which would be 0 for a river that drained into the ocean, but can be different for a river that drains into a lake), L is the length of the river from its ultimate source to its outlet, x is the distance downstream from the source, U is the uplift rate, P is the precipitation rate and K is a constant. Thus a plot of $h-h_0$ against L/x on semilog paper should produce a straight line.