12.001 **Due: Monday November 26th**

LAB 7: Rivers and Flood Frequency

Overview and Objectives

This exercise will provide some hands-on experience with methods used for predicting flood frequency and magnitude. We will be using the US Geological Survey (USGS) website to retrieve historical stream gauge data of the sort used to predict the likelihood of flood events of particular magnitudes during a given time interval. Such predictions are the basis for numerous engineering, restoration and development projects in and around rivers.

We will retrieve data for a river in Oregon, use a spreadsheet to analyze the data, and assess the probability of occurrence of floods of particular magnitudes (in terms of discharge), or the likely magnitudes of events of a given recurrence interval. We will then repeat the exercise for the Taunton River in southeastern Massachusetts.

Assignment: Part I

Data acquisition

Point your web browser to the USGS National Water Information System (NWIS) at http://waterdata.usgs.gov. For a flood frequency analysis, the quantity most often used is the annual peak discharge, so select **Surface Water → Peak-Flow Data**. We will use the gauge on the **Willamette River** at Salem, Oregon, which has an unusually long record extending back more than a century. Tick the box to **search by site number**, and click Submit. **Enter site number 14191000,** scroll to the bottom, and **select Tab-separated data** (YYYY, MM, DD columns / Save to file). Save the file with the extension ".txt".

Open the file in a spreadsheet (remember we are using **tab delimited** data). Start by copying all the data to a separate worksheet and cleaning it up: the only pieces of information we need for this exercise are the **date of each flow, the peak discharge, and the peak gauge height.**

Flood frequency analysis

Sort your data table in descending order of discharge, such that the largest discharge on record is in the first row. We now have a list of the annual peak flows on the Willamette River from the late 19th century to the present (with a few gaps), listed in order of discharge from highest to lowest. Insert two columns between the date and the discharge. The first column will be the flood "rank" (r) from largest (rank = 1) to smallest (rank = number of observations). The next column will be recurrence interval (RI).

The recurrence interval of a flood of a given magnitude indicates how often we expect a flood of that magnitude or larger to occur. RI is commonly estimated as:

$$\mathrm{RI} = \frac{1+n}{r}$$

where n is the number of years on record (which can be less than the *duration* of the record, if some years are missing). For example, RI for the December 1964 flood of 308,000 cfs ($r = 8$) is (1+119 yr)/8 = 15 yr. Create a formula in the spreadsheet to calculate RI for each of the floods on record. The probability of a flood of a certain magnitude occurring in a given year is simply 1/RI. For example, a flood with the magnitude of the 1964 event has a 1/15 = 6.7% probability of occurrence in a given year.

Graphical analysis

We will now proceed with a graphical analysis of the record. The usual procedure is to assume that the frequency distribution of floods in our record conforms to a known distribution, and plot the observed floods in such a way that they will fall along a straight line if the data conform to the assumed distribution. Distributions in common use include the Gumbel, Weibull, and Pearson Type III distributions, all of which are designed to characterize extreme value phenomena.

To keep our analysis simple, we will assume that flood frequency is lognormally distributed. This implies that there should be a semilogarithmic relationship between flood magnitude and RI. Plot discharge (on the y-axis) against RI (on the x-axis) for the Willamette data. Change the RI axis to a logarithmic scale. Add a logarithmic trendline to evaluate the fit, and find the equation of the trendline. Make the trendline extend out to a 1000 year RI. Add major and minor vertical gridlines to the plot.

Use the data table and plot to answer the following questions:

1. What is the recurrence interval of the Willamette River's mean annual discharge?
2. Are there any parts of your plot that do not appear to follow the semilogarithmic trend? If you were an engineer trying to define a reliable empirical trend, how might you modify your graphical analysis?
3. What is the recurrence interval of a flood with discharge of at least 200,000 cfs?
4. What is the discharge of the "50-year flood"? The "100-year flood"? These two hypothetical events are sometimes used by engineers and planners.
5. What is the discharge of the 1000-year flood? How do you feel about the reliability of this prediction compared to the 50- and 100-year predictions? Why?

Rating curve

Now make a plot of peak gauge height (on the y-axis) against peak discharge (on the x-axis). The result is a "rating curve," which can be used to predict the water level (stage) for a given flood discharge. Clearly this is critical information for planning purposes. Note, however, that something is amiss with this plot: there appear to be two distinct relationships between stage and discharge.

6. Why are there two distinct relationships? [Hint: examine the dates associated with the points on each of the "branches."] Does this affect our ability to accurately predict flood stages?
7. Use the upper branch on the rating curve plot to estimate the stage that would be predicted for the 50- and 100-year floods. Would the stage prediction for a 1000-year flood be more or less certain than the discharge prediction? Why?

Assignment: Part II

Next, follow the same procedure outlined above to perform a flood frequency analysis for the gauge on the Taunton River near Bridgewater, MA (site 01108000). The Taunton River is the longest undammed coastal river in New England, and its watershed is the second largest contained within Massachusetts. Use your data table, flood frequency plot, and rating curve to answer the following questions:

8. Are there any parts of your plot that do not appear to follow the semilogarithmic trend? Report any corresponding modifications to your graphical analysis.
9. What is the discharge of the "50-year flood"? The "100-year flood"?

Assignment: Part III

Now let's compare the predictions of our flood frequency analysis with the major storms that hit New England in March 2010. Return to http://waterdata.usgs.gov, but this time navigate to **Surface Water → Real-time data**, and **select Daily Stage and Streamflow / no grouping / 01108000**. Hit "go". Click on the station number to select the Taunton River at Bridgewater. **Select "Time series – daily data"** and hit "go". Download the peak daily discharge from January 1, 2010 through April 30, 2010 in tab-delimited format. Open the data in a spreadsheet, and make a plot of the peak daily discharge vs. date during this interval. Find the peak flows that occurred in response to the two storms of mid-March and late March. Plot a horizontal line on your flood frequency plot corresponding to each peak flow.

10. What stage does your rating curve predict for each peak flow?
11. Based on your analysis, what is the recurrence interval of the mid-March storm? How long had it been since the Taunton River most recently exceeded this discharge? How does that time interval compare with the one you predicted?
12. What is the recurrence interval of the late March storm? How long had it been since the Taunton River most recently exceeded this discharge? How does that time interval compare with the one you predicted?
13. Comment on the comparison between your answers to the two previous questions. How reliable was your flood frequency analysis?
14. If you were an engineer charged with advising the city of Taunton (about 10 miles downstream of Bridgewater) on future flood control measures, what would you tell the city officials?
15. How would your flood frequency analysis be complicated if we were to choose a river with several large dams along its course?

Hand in:

- Spreadsheets showing flood frequency analysis for both rivers
- Flood frequency plots and rating curves for both rivers
- Time series plot of peak daily discharge for the Taunton River
- Answers to all numbered questions in this handout

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