Rivers and Flooding

Goals:
-Explore the relationship between the size of floods and how frequently they occur.
-Learn how to input, manipulate, and plot data in Microsoft Excel.
-Learn why flooding occurs and how human actions affect the frequency of large flooding events.

Materials:
-pencil and eraser
-a colored pencil
-a straight edge
-a computer with access to the Internet and Microsoft Excel
-your textbook for reference

Introduction:

One of the most dangerous natural hazards that humans face is flooding. The deadliest flooding event on record is a series of floods that occurred in central China in 1931: the death toll from this event is estimated to be somewhere between 2.7 and 3.5 million people. By comparison, the deadliest earthquake on record, an 8.0 earthquake that occurred in 1556 in northwest China, has an estimated death toll of 0.83 million people. Besides having devastating potential, floods are dangerous simply because so many people live in flood hazard areas: because rivers provide fertile land area, many people live along their banks (whereas a relatively smaller number of people live along plate boundaries subject to earthquakes and volcanoes).

If you stand in a river, the amount (volume) of water that flows by you every second is known as the river's **discharge**. When more water is forced to flow through the river (e.g. due to excessive rainfall), then the discharge must increase. When the discharge is too much for the river to handle, the water cannot be contained and the blanks will overflow, leading to a flood. In this lab, we will explore the relationship between the size of floods and their frequency, and we will investigate the causes of flooding.

Describing the Size of a Flood:

The size of a flood can be described by the river's **discharge** during the flooding event, or by how high the river's banks reach above their normal level (the **gage height**). The frequency of a flood is described by its **recurrence interval**. The recurrence interval of a flood is the *average* time between floods of this size. For example a "50-year flood" occurs on average every 50 years. Note that this *does not* mean that this size flood occurs every 50 years, like clockwork. It means that in any given year, the chance of a "50-year flood" happening is 1/50, or 2%. *It does not matter what happened the previous year*. This is similar to flipping a coin: each time you flip a coin, you have a 50% chance of getting heads, even if you got heads the previous 10 times that you have flipped the coin!

The Relationship Between the Size of a Flood and the Recurrence Interval:

In this section we are going to plot the size of a flood versus the recurrence interval for a specific river, the Lehigh River in Bethlehem, Pennsylvania, to see if there is any relationship. To do this, complete the following steps:

Step A – Go to http://nwis.waterdata.usgs.gov/pa/nwis/peak?site_no=01453000&agency_cd=USGS&format=html (on the computers in the lab, this link is under the bookmark titled "Lehigh River Data") and copy and paste the stream-flow data for 1902 to 1960 into an excel spreadsheet. We are only using data up to 1960 because beyond then the stream-flow was regulated and diverted. Your spreadsheet should have four columns: the year (column A), the date that the biggest flood occurred that year (column B), the gage height recorded during that flood in feet (column C), and the stream-flow (i.e. discharge) recorded during that flood in cubic feet per second (column D). Put the data starting in row 2 and put labels for the columns in row 1. BEWARE: the discharge for 1903, 1904, and 1905 will be copied incorrectly into Excel using cut and paste because of the footnote reference. You will need to fix these discharges by hand.

Step B – Sort the data so that it is arranged with the biggest flood in the top row and the smallest flood in the last row. To do this, select all the data in the table. Then from the "Data" menu, choose "Sort," and sort descending (largest to smallest) by stream-flow (column D). To do this choose "Column D" in the drop down menu labeled "Column" and "Largest to Smallest" in the drop down menu labeled "Order." Click "ok."

Step C – Determine the rank of each flood and record it in column E. The biggest flood is given a rank of 1, the second biggest flood is given a rank of 2, and so on. This is easy to do since you have already sorted the data! If your data for 1942 (the biggest flood) is in row 2, then type "1" in E2. In E3 type "=E2+1." Then grab (click on) the bottom right-hand corner of box E2 (the cursor should become a thin cross) and drag the cursor down all the way to the bottom row of data. The rankings should automatically fill in.

Step D – Calculate the recurrence interval for each flood and record it in column F. The recurrence interval can be calculated using the following equation:

$$R = (N+1) / m$$

Where R is the recurrence interval (in units of years),
N is the total number of floods on record (here, 55),
and m is the rank of the flood

To do this, type "=(55+1)/E2" in box F2. Then grab (click on) the bottom right-hand corner of box F2 (the cursor should become a thin cross) and drag the cursor down all the way to the bottom row of data. The recurrence intervals should automatically fill in.

Step E – Make an X-Y scatter plot graphing the recurrence interval on the X axis (horizontal axis) and the discharge on the Y axis (vertical axis). To do this, from the "Insert" menu, choose the first option under "Scatter." Right click the plot/rectangle that shows up and choose "Select Data." Remove any data that was automatically entered (if any shows up; if a blank white rectangle shows up that is ok too). To do this highlight each entry in the white box on the left and click "Remove." Then choose "Add." Click on the "Series X values" box and then highlight the recurrence interval data (Column F) on the spreadsheet. Next, click on the "Series Y values" box, delete what is already written there, and then highlight the stream-flow data (Column D) on the spreadsheet. Click "ok." Then click "ok" again.

Step F – Change the X axis to a logarithmic scale. To do this, right click the X axis and choose "Format axis." Under "Axis options," check off logarithmic scale. Click "Close."

Step G – Add tick marks to the axes to make them easier to read. To do this, first right click the X axis and choose "Format axis." Click on the drop down menu labeled "Minor tick mark type" (in the middle of the box) and choose "Cross." Click "Close." Do the same for the Y axis.

Step G – Label the axes of your plot and give it a title. To do this, choose the first "Chart Layouts" option under the "Design" menu. Label the X axis "Recurrence Interval (Years)," the Y axis "Discharge (cfs)," and the title "Recurrence Interval Versus Discharge."

Step H – Draw a best-fit line through the points on the graph. To do this, right click the data points on the plot (clicking any point will work) and select "Add Trendline." Choose a "Logarithmic" trendline and click "ok"!

Print out your plot to hand in at the end of lab. Be sure to write your name and the name of your lab partners on the plot. Then, using this plot, answer the following questions on the answer sheet found at the back of this lab:

1. ***In general, as the recurrence interval increases, does the discharge increase or decrease? Does this mean that larger floods occur more or less frequently than smaller floods?***
2. ***What is the discharge associated with a 10-year flood on the Lehigh River?***
3. ***On average, what is the time interval between floods that have a discharge of 20,000 cubic feet per second on the Lehigh River?***
4. ***Between 1902 and 1960, was there a 100-year flood on the Lehigh River?***
5. ***What is the discharge associated with a 100-year flood on the Lehigh River?***
6. ***How reliable do you think your number from question 5 is? What are some of the errors that could be associated with this number?***
7. ***Figure 1 plots the gage height of a flood on the Lehigh River versus the discharge of the flood, as well as a best-fit line for this data. Using your answer from question 5, how high would a 100-year flood reach above the normal water level?***
8. ***The map at the end of the answer sheet displays the topography around the area of the Lehigh River where this data was taken (the data station is represented by a triangle). Using a colored pencil, shade in the areas around the river that would experience flooding during a 100-year flood. The river itself is at an elevation of about 310 feet.***

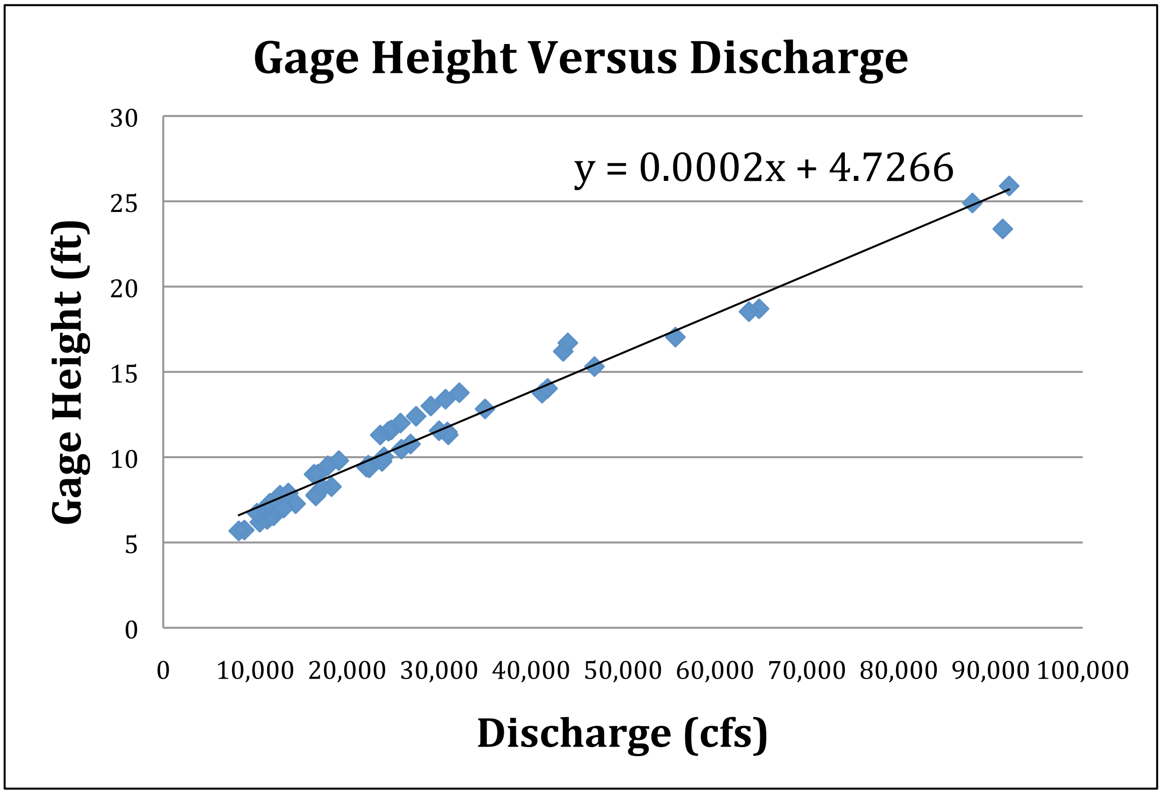

Figure 1: Gage Height Versus Discharge for floods on the Lehigh River in Bethlehem, PA.

Causes of Flooding:

Rivers flood when too much water is input into them. Thus flooding can result when there is excessive rainfall or snowmelt. A **hydrograph** is a plot that shows the discharge of a river over time and provides a good way to visual a flooding event. Figure 2 shows a sample hydrograph. During a flood, the discharge rises (rising limb) to a peak (peak discharge), and then falls back down to normal (falling limb). Note that there is a lag time between the peak rainfall and the peak discharge. This is because it takes time for precipitation to reach a river – it must first travel on top of the ground (as surface runoff) or through the ground (after it soaks in). Because some of the water runs straight over the surface to the river, and some of it soaks in first, the water reaches the river at different times. This is why there is a gradual rise to the peak instead of an abrupt rise.

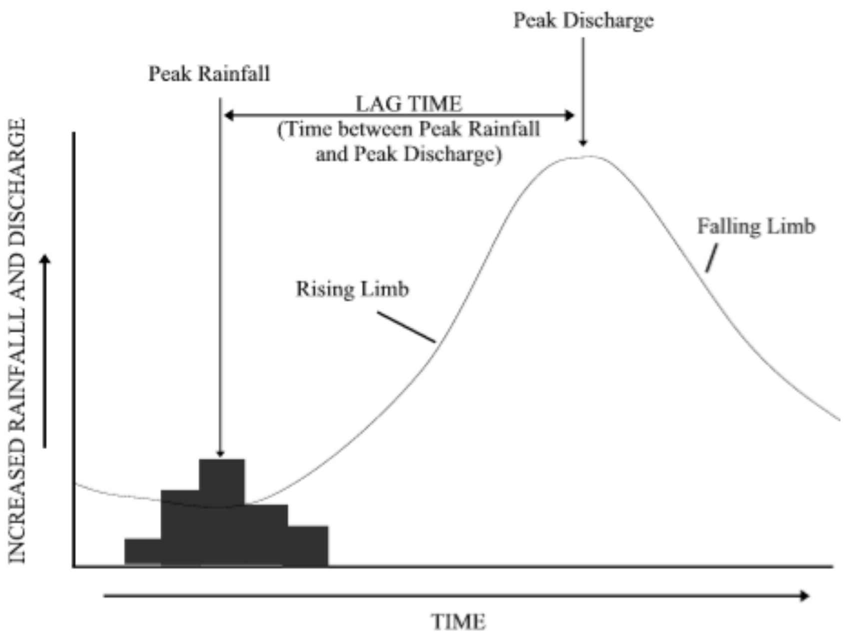

Figure 2: Example of a hydrograph.

To see how human activity can affect the frequency of flooding events, answer the following questions on your answer sheet:

1. ***In 2010, the chance of a flood with a discharge of 10,000 cubic feet per second occurring on River X is 2%. What is the recurrence interval of this flood?***
2. ***Suppose that the 2010 hydrograph for this flood is represented by the sample hydrograph in Figure 2. Now in 2011, further suppose that concrete parking lots are built over much of the area around River X. Will the presence of these parking lots increase or decrease the amount of precipitation able to soak into the ground?***
3. ***Based on your answer to question 10, will the lag time between the peak rainfall and the peak discharge increase or decrease because of the parking lots?***
4. ***Based on your answers to question 10 and 11, will the peak discharge increase or decrease because of the parking lots? Thus, will the presence of the parking lots make the flood larger or smaller than it would be otherwise?***
5. ***The hydrograph on the answer sheet shows the 2010 hydrograph. On this plot, draw what the hydrograph would look like in 2012 (after the parking lots are built!) for the same rainfall event.***
6. ***Is the chance of a flood with a discharge of 10,000 cubic feet per second occurring in 2012 on River X less than 2%, equal to 2%, or greater than 2%?***
7. ***In a few sentences, describe how urbanization (constructing cities with buildings, parking lots, etc.) affects the frequency of large flooding events.***