GEOL-301, Hydrology
Bader, Spring 2013 **Name:**

Lab 8:
Working with discharge data

Goals:

- Gain proficiency in finding and using USGS discharge data.
- Understand how long-term flood frequency is calculated.
- See how a simple flood map can be drawn using discharge data.

You will hand in: This lab packet, an Excel spreadsheet, and a flood map.

Overview: *In this lab you will get up-to-date gaging station data for Walla Walla rivers and apply the data to answering questions about flooding and discharge variability.*

---

1 Introduction to USGS discharge data

The USGS maintains a website that allows you to view real-time discharge data from a subset of the USGS gaging stations. (At some stations this data must still be collected manually.) This is an amazingly powerful tool.

- Open a browser and navigate to the USGS real-time water data website at `http://waterdata.usgs.gov/nwis/rt`
- Go to the Washington State data. Notice the colored dots, depicting real-time conditions at stream gages statewide. The dots are colored to show you if the streamflow is unusually high or low for this time of year. Note that "unusual" is a matter of degree; while the 25-74th percentile category is certainly not unusual, the next higher and lower categories (between the 10th and 90th percentiles) are perhaps mildly unusual. Discharges greater than 90th or less than 10th are occur about 20% of the time, on average.

1.1 Hydrographs

Click on the stream gage dot on Mill Creek at Rooks Park ("Mill Creek at Walla Walla" will appear when your cursor hovers over the correct dot on the map). You will see a real-time *hydrograph* incorporating discharge data from the past week. A hydrograph is a plot of river discharge vs. time.

Exercise:

1. Describe the shape of the hydrograph. Does the shape make sense given what you remember about the precipitation we've felt over the past few days?
2. What was the *peak discharge* (maximum discharge) over the past week, and when did it occur?
3. What was the peak discharge for the next station downstream (Walla Walla River near Touchet) over the same time period, and when did it occur?

2 Monthly summaries

We can also look at summaries of the stream data.

- Still at the "Walla Walla River near Touchet" gaging station, use the drop-down menu to select "Monthly statistics."
- Click on the checkbox to select the Discharge parameter, and click the "Submit" button.
- You can scroll to the bottom of the resulting table to see the mean discharge for each month.

Exercise:

1. What months had the lowest discharge?
2. What months had the highest?
3. What do you think is providing much of the water during the highest-discharge months?

3 Daily data

Let's look a little further into the data available for this gaging station.

- Still in the "Walla Walla River near Touchet" page, select "Daily data" from the dropdown menu.

- Request all available daily data for the ten-year period 1996-01-01 to 2006-01-01 in tab-separated format. Click anywhere in the resulting document, then type `Ctrl-a` to select all and then `Ctrl-c` to copy the text to the clipboard.

- Open Excel. Click on the top left cell of your worksheet and then find the Paste button on the far left side of your Home tab. Click the drop-down arrow and choose Paste Special, selecting "Text." Hopefully the data will be properly arranged in cells in the worksheet (you need to scroll down to see where the data starts). At the bottom of the window, name this worksheet "Daily data".

  Note: If a column is filled with hash signs (#) instead of numbers, then the column is not wide enough to display the data. Make the column wider by clicking on the line separating this column's letter from the next, then dragging it to the right.

- Immediately save the resulting Excel file in your personal folder.

3.1 Making a rating curve

A *rating curve* shows the relationship between discharge and gage height.

- First, let's clean up the spreadsheet. All you need to do this exercise is discharge, but you should also keep the columns containing gage height and the date of the measurement.
  - Delete unnecessary columns.
  - Give your remaining data columns understandable column names, like `discharge(cfs)`.
  - Delete the header rows above the table.

- For this exercise, we need to delete two outliers. During two days during the flood of 1996, the gage/discharge relationship was different from the others. We need to remove these points in order to have a readable graph. Delete the two rows from 2/10/1996 and 2/11/1996.

- Change the order of the columns using copy and paste so that gage height comes before discharge.

- Select the data in these two columns, including the column labels, by clicking on the top left cell and shift-clicking on the lower right cell.

- Find Charts in the Insert tab. Select an X-Y scatterplot with no lines connecting the points. You should see a plot of discharge (on the Y axis) as a function of gage height (on the X axis).

- You can move the chart to a new worksheet by right-clicking it and selecting Move Chart. Call the new worksheet "Rating Curve."

Exercise:

1. Describe the relationship between gage height and discharge.

2. Given this relationship, do you think the precision of the discharge data is better at relatively low discharge or high discharge? Why? (Hint: think about how a 100 cfs increase in discharge would look when the river is high and when it is low.)

3. What is the gage height at the lowest discharge measured?

4. (a) Going back to the data table, approximately how much water in cubic feet flowed past the gaging station per year on average? (Hint: remember discharge is in volume per second. You can add another column showing daily volume.)

   (b) In cubic meters?

4 Frequency analysis

We can use the peak data provided by the USGS to ask questions about the likelihood of flood events.

- Add a new worksheet to your Excel spreadsheet, and rename it "Peak data".
- Back at the USGS website, select "Peak Streamflow" from the dropdown menu.
- Select "Tab-separated file." As before, copy the text and then use "Paste special" as text to get the data into your new Excel worksheet.

Exercise: Examine the data.

1. What years are covered by this dataset?
2. Find the maximum discharge on record during this time.
   (a) When did it occur?
   (b) What was the discharge in cfs?
   (c) What was the gage height during this discharge?

- Clean up the spreadsheet as you did with the daily data. You should keep the date, gage height, and discharge columns.
- Using the Excel functions `AVERAGE()` and `STDEV()`, calculate the mean and standard deviation of discharge for this dataset.

Remember that to enter a formula, you must first type '=' and that you can refer to cell contents by their position. An example formula to calculate the mean of some numbers in column B between rows 3 and 7 might therefore be: `=AVERAGE(B3:B7)`

Exercise:

1. What is the mean peak discharge across all of the years (always include units)?
2. What is the standard deviation of peak discharge?
3. Approximately how many standard deviations above the mean was the highest peak discharge?

4.1 Ranked discharge

We can use peak data such as this to calculate the probability of floods of a particular size. This is how we figure out that a particular discharge is e.g. "a 100-year flood" for a given stream.

Discharge probability is the probability of experiencing a flood of this large *or larger* in any year.

Long-term recurrence interval is a misleading term. It is equal to $1/p$ where p is the discharge probability. A flood frequency of 100, for example, means that a discharge this high or higher is a "100-year flood," which means that over a very long period you can expect to see about one flood of this size per 100 years of record.

Exercise: Given the way flood frequency is calculated, if there was a 100-year flood two years ago, how long would you have to wait for the next 100-year flood? (Careful, this is a trick question!)

- Copy the all of the Peak Discharge data to a new worksheet. Name the worksheet "Flood."
- Now use the "Sort Z to A" function to sort the data from the highest discharge at the top to the lowest at the bottom.
- Add a new column, named `Rank`. In the top row, with the largest flood discharge on record, put a "1" in the Rank column. Then rank the remaining peak discharges:
  - In the Rank column, in the cell just below the "1," type a formula adding one to the cell above it, and hit return. There should now be a "2" in the cell.
  - Select the cell with the formula, and shift-click on the last cell in the Rank column to select the rest of the column.
  - Type `Ctrl - d` to fill the formula into the remaining cells.
- Now start a new column, called `Probability`. For this column, we can calculate the probability of a discharge this large or larger, based on the data. We will calculate this as the total number of peak events this high or higher divided by the total number of events on record, or $P = R/(n+1)$ where R is the rank and n is the total number of events on record.

  Note: we adjust the denominator by one to correct a systematic bias and reflect our uncertainty. You can see that if we only had one discharge on record, it would be more sensible to make assign a probability of 50% rather than 100%.
- Use a formula to calculate the discharge probability for each discharge.
- Make a new column, and calculate the long-term recurrence interval, or $1/P$.
- Plot your results. Make a new X-Y scatterplot with Recurrence Interval on the X-axis and Discharge on the Y axis. Make both axes logarithmic.
- To improve readability, right-click on the numbers along an axis and select "add minor gridlines."

Exercise:

1. (a) Based on your graph, what discharge is a 50-year flood for this basin?

   (b) How about a 100-year flood?

4.2 Flood stage

Flood stage refers to an arbitrary gage height at which there is “significant” inundation and flooding — that is, flooding that threatens lives, properties, or commerce. This definition only makes sense in populated areas; elsewhere it is undefined. For unpopulated areas you might define flood stage as the gage height at which the flow spills out of the river channel. Since real streams are not regular in shape, this definition is also subjective.

Exercise:

1. From the USGS website, what is flood stage for the Walla Walla near Touchet?
2. From the rating curve you made, approximately how much discharge is occurring when the gage is at flood stage?
3. From your flood frequency analysis, what is the long-term recurrence interval of discharge events at least this large?
4. From the USGS website, what is the elevation of the gage above sea level in feet?
5. If the Walla Walla River has just reached flood stage, what is the elevation of the top of the floodwaters in this area, in feet and in meters?

4.3 Modeling flood inundation area with ArcGIS

If we know the flood stage near a particular gaging station, then we can use ArcGIS to quickly generate a map of the potentially-flooded area.

- Copy the folder located at `M:\geol301\discharge_data` to your personal folder on the `D:` drive.
- Fire up ArcMap and drum your fingers impatiently while it loads. Open a new empty map.
- Use the “Add data” button to add the datasets in the `discharge_data` folder.

  `topo24k` is a scanned USGS 7.5-minute quadrangle map.

  `elevation` is a digital elevation model. This is a rectangular grid of cells, in which each cell contains a number representing elevation in meters above sea level. By default, higher elevations are shown in white.

- Notice that you can only see one of these datasets at a time. Check the boxes next to each layer in the Table of Contents (the pane on the left) to toggle visibility of each layer. You can also use the magnifying glass tool to zoom into your data. Notice that the topographic map image is only effective at a particular level of zoon.
- Make sure the Spatial Analyst extension is enabled: go into Customize → Extensions and make sure there is a check mark next to “Spatial Analyst.”

- Type Ctrl-F to open the Search window. Type "Raster Calculator" into the search box and press return. Then select the Spatial Analyst tool of the same name to open it.

You will use a *conditional expression* to locate the cells in your digital elevation model that are below flood stage. A conditional expression generates a new grid of cells based on your criteria. The syntax is:

`Con(` {condition to test for each cell}, {value to assign if the condition is true}, {value to assign if the condition is false} `)`

We will test the condition that the elevation in each DEM cell is less than or equal to the elevation of the top of the water at flood stage.

Note: When you enter an expression in the Raster Calculator, you have to type the commas — for everything else you should use the keypad, because it will add the correct number of spaces for you. You can input "Con" by double-clicking it in the list on the right; input the name of the elevation data by double-clicking it in the list on the left.

- In the Raster Calculator window, enter the expression `Con("elevation" <=` E_f`, 1, 0)`, where E_f is the elevation, in meters, that you determined for the top of the water at flood stage.
- In the "Output raster" field, click the folder icon to choose a location in your personal folder and an appropriate name for your calculation. Click "OK" — it will take a minute to calculate. A new layer should appear in the Table of Contents. Each cell in the raster contains a "1" if it would be flooded and "0" if it would not.
- Right-click on the Calculation layer and select "Properties." Click the Symbology tab.
  - First, click on the row showing the color of the zero values. Click the "Remove" button to stop drawing those cells.
  - Double-click on the colored rectangle next to the "1." Change the color to something appropriately watery.
  - Still in the Properties dialog box, click on the Display tab and set the transparency to 50%. Click "OK."
- Make sure that the topo map is visible underneath the flood zone. Zoom in to take a closer look at the flood boundaries.

Exercise:

1. Does your map look reasonable?
2. Describe the flooded area. What are its extents on the map?
3. Why does this type of analysis only work for small geographic areas? How could we do a better job?
4. Go to a location of your choice on the map. Take a screenshot using the Print Screen button on your keyboard and paste the image into a new worksheet in your Excel document.

You're finished! Be sure to upload your Excel spreadsheet and your map screenshot to your CLEo dropbox.