**Problem Statement:** How high should the boathouse be built to avoid flooding?

**Background:** The University of Portland plans to build a boathouse on the Franz River Campus. Your task is to make a recommendation on how high the building should be raised in order to reduce the probability of flooding to an acceptable level. For this project, we will use the National Geodetic Vertical Datum of 1929 (NGVD29), which is an estimate of mean sea level, as the reference for elevations. The current ground level of the boathouse site is 28.6 feet above NGVD29 (see Figure 1).

**Resources:** The file GageHeightMorrisonBridge.xlsx has gage height values provided by U.S. Geological Survey from the Willamette River gage at the Morrison Bridge in Portland. The data was recorded several times per hour for many years. The gage datum, which is the zero point of the gage, is 1.55 feet above NGVD29. The river height (above NGVD29) is the gage height plus 1.55 feet (see Figure 1).

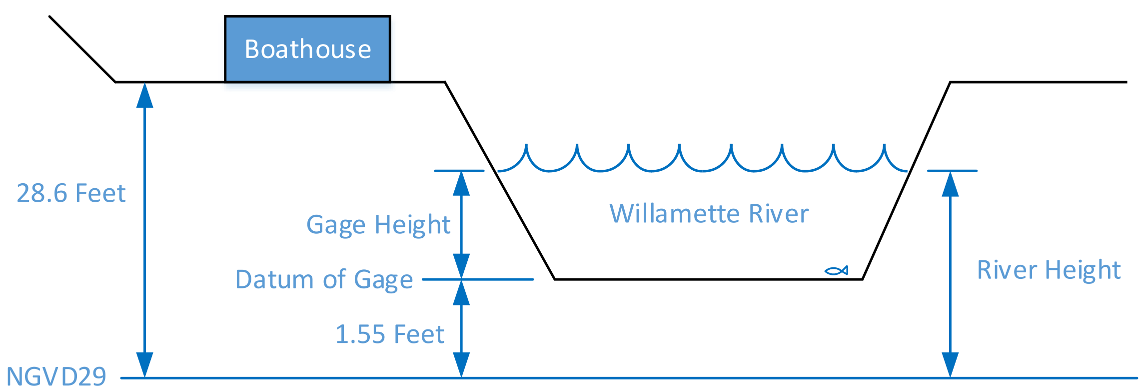


Figure 1: Location of Boathouse, Gage, and NGVD29

**Explore the Data:** Before analyzing a set of data, you should explore the data to understand its form and meaning. Some example questions are the following: Which years are covered by the data? Are there gaps in the data? What does a plot of the river height look like over the span of a couple of days? What does a plot of the river height look like over the span of a year? Which year had the highest river height? Did the site of the boathouse flood in the year with the highest river height?

**Procedure:** Write a MATLAB **function** called **returnPeriod** that computes the return period for various river heights (see Appendix for details of how to compute return period). The input to the function returnPeriod is a vector of yearly maximum river heights and the output consists of three vectors: the yearly maximum river heights ranked in descending order, the return period for each ranked river height, and the probability of exceedance. Test your function by copying the commands from the file testReturnPeriod.txt, which is available on the course website, pasting them into a script file (or saving the file with extension .m), running it, and comparing results to the values in Table 2.

Also write a MATLAB **script file** called **boathouse.m** that does the following:

1. Loads in the data file GageHeightMorrisonBridge.xlsx
2. Includes your code from the section "Explore the Data"
3. Computes the yearly maximum river height for each of the years in the data file
4. Calls your returnPeriod function
5. Prints to the command window a table of return periods and probabilities of exceedance values similar to Table 2 for all the years in the data file

Note: It takes a long time to load in the data file because it is so large. To avoid loading in the file repeatedly, after you run the file once, you might want to comment out the "clear" command and the xlsread command to allow your script to use the data that is already stored in the Workspace instead of loading the file again.

Finally, using the table of return periods and probabilities of exceedance, develop your recommendation for the height that the boathouse should be built and justify your recommendation with relevant economic, safety, environmental, and ethical factors. Each team will present their recommendation and justification in a short memo.

**Deliverables:** Please upload the following items to Moodle (one submission per team):

1. The files boathouse.m and returnPeriod.m (make sure to comment your programs!)
2. A short memo (in .pdf format) presenting the team's recommendation and justification.

**Appendix: Return Period and Probability of Exceedance**

The return period and probability of exceedance are used to evaluate the risk of flooding. The return period is the estimated average time between floods at a given level or above. So, for example, if a flood of a given height has a return period of 100 years, that means that **on average** we expect a flood that high or higher every 100 years. This does not imply that a flood will occur exactly once every 100 years, and it does not imply that in a given 100-year interval there will be exactly 1 flood. In a given 100-year period, there might be no floods, 1 flood, or more floods, but **on average** we expect 1 flood.

The probability of exceedance is the probability of a flood of a given height or higher occurring in a given year. It is the reciprocal of the return period.

In order to demonstrate how to compute the return period and probability of exceedance, consider data in Table 1, which is based on the last ten years in the file GageHeightMorrisonBridge.xlsx. Note that Table 1 contains river height (above NGVD29), which is the gage height from the file plus the gage datum (1.55 feet).

Table 1: Yearly Maximum River Height

| Year | Yearly Max River Height (feet) |
|---|---|
| 2018 | 17.1 |
| 2017 | 18.8 |
| 2016 | 12.5 |
| 2015 | 13.9 |
| 2014 | 14.8 |
| 2013 | 11.6 |
| 2012 | 17.4 |
| 2011 | 18.6 |
| 2010 | 16.1 |
| 2009 | 15.5 |

First the Yearly Maximum data are ranked in descending order (see Table 2). Then the return period is computed by $T = \frac{n+1}{m}$ where n is the number of values in the dataset (n = 10 in this case) and m is the rank number. So, for example, the return period of an event with river height of 18.8 feet or greater is $T = \frac{n+1}{m} = \frac{10+1}{1} = 11$ years (See Table 2). The probability of exceedance of an event with river height of 18.8 feet or greater is $P = \frac{1}{T} = \frac{1}{11} = 0.09$. Therefore, based on this dataset, we would expect a river height of 18.8 feet or greater to occur every 11 years on average. The probability of a river height of 18.8 feet or greater in a given year is 0.09.

Table 2: Return Period and Probability of Exceedance

| Rank | Sorted Yearly Max River Height (feet) | Return Period (Years) | Probability of Exceedance |
|---|---|---|---|
| 1 | 18.8 | 11.00 | 0.09 |
| 2 | 18.6 | 5.50 | 0.18 |
| 3 | 17.4 | 3.67 | 0.27 |
| 4 | 17.1 | 2.75 | 0.36 |
| 5 | 16.1 | 2.20 | 0.45 |
| 6 | 15.5 | 1.83 | 0.55 |
| 7 | 14.8 | 1.57 | 0.64 |
| 8 | 13.9 | 1.38 | 0.73 |
| 9 | 12.5 | 1.22 | 0.82 |
| 10 | 11.6 | 1.10 | 0.91 |